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FINAL REPORT

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A TECHNIQUE FOR ESTABLISHING TRUE LEVELS OF MUSCLE STRENGTH EXERTION

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...ical Information Officer

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Experiments were performed with 20 female and 20 male subjects in order to determine indicators of whether the subjects performed maximal or submaximal isometric strength exertions. The exertions tested were elbow flexion, finger flexion, knee flexion and knee extension. The only performance measures used were analog recordings of the strength scores exerted on a static dynamometer.

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Continued from Block 20 - Abstract

1. The variability of tests scores in repeated exertions is not a viable indicator of the actual portion of individual strength exerted.

2. The buildup phase of strength exertion is a reliable indicator of the force level to be attained. The steeper the strength formation curve, the stronger the following muscle strength exertion.

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BACKGROUND INFORMATION

Testing of maximal muscular capabilities is crucial for the selection of persons for their ability to perform physically demanding work. It is also crucial for the establishment of job requirements so that they do not overtax the muscular capabilities of persons who have to perform the work. Thus, muscle strength testing provides both personal selection criteria and design guidelines, either for equipment design or for task performance parameters.

Obviously, it is critical to know whether or not a subject exerts a maximal effort during a muscle strength test, or if in fact only a submaximal exertion is exhibited. Physiologists, ergonomists, physical educators, and experimental psychologists have described many procedures that supposedly bring about a subject's best effort (Astrand and Rodahl 1977; Drury 1978; Hettinger 1972; Kroemer 1970, 1974, 1975, 1977, 1978, 1979; Marras 1978; Marras and Kroemer 1979; Rohmert and Sieber 1960). The discussions concern, among other as pects, whether or not exhortations should be used, how motivation can be influenced, whether active or passive muscle tensions should be employed, how long the buildup phase of muscular contraction should last, whether smooth or abrupt muscle contractions should be employed, what role feedback of the exerted score plays, etc. While, in essence, many of the questions are still unanswered, a standard procedure has been proposed in 1974 (Caldwell et al. 1974) and has been used since.

This procedure controls the experimental conditions and describes a step-by-step testing technique. It has become largely accepted throughout the world as the standard muscle strength testing procedure.

Within this procedural framework tests have been indicated the feasibility to assess, in a rather simple experimental arrangement, whether or not a test subject exerts truly maximal strength scores (Kroemer 1979; Marras 1978; Marras & Kroemer 1979). The following text describes related experiments. They were performed to address principally the following questions:

1) Do repeated exertions have less variability at submaximal strength levels than at maximal levels?

2) Is the initial speed of strength formation related to the amount of strength finally exerted?

A MODEL OF STRENGTH EXERTION

In order to exhibit a given strength score at a dynamometer, the subject contracts the muscles involved in a definite manner. Thus, the strength score to be exhibited determines an "executive program" in the cerebral and cerebellar parts of the central nervous system, CNS. According to this program, nervous impulses are sent from the CNS to the muscles along the efferent pathways, E. Figure 1 depicts a model of this network (Kroemer 1979).

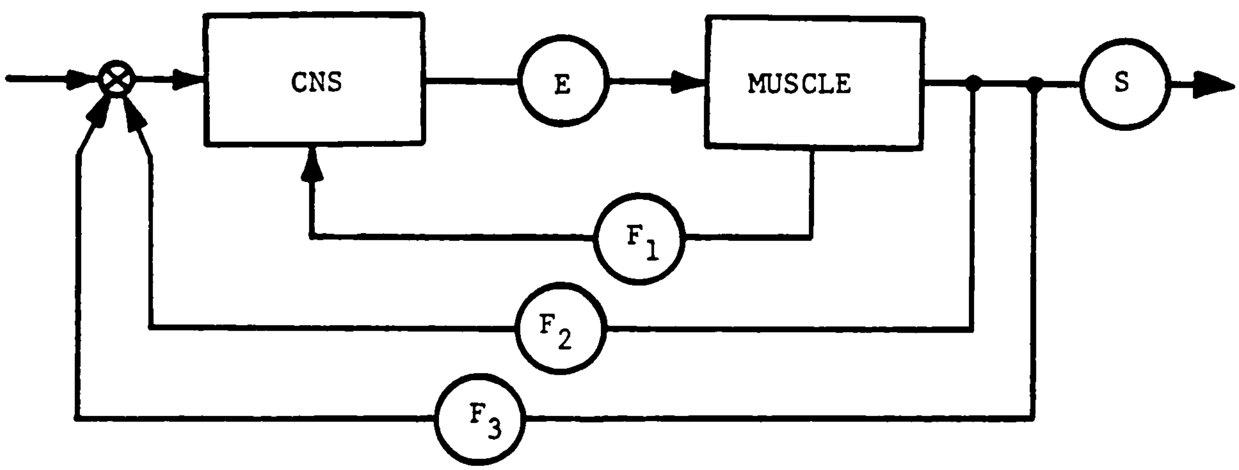

Figure 1: Model of the Regulation of Muscle Strength Exertion (Kroemer 1979)

CNS: Central Nervous System (cerebral or cerebellar centers)

E: Efferent excitation impulses generated according to the Executive Program in the CNS

F_1, F_2, F_3: Afferent feedback loops

S: Strength output measured at an external dynamometer

While the muscle bundles involved contract, feedback about the contraction status is provided along several afferent pathways. In the model, they are simplified into three different loops. The primary feedback F_1 stems from the Golgi tendon and spindle organs of the primary active muscles. Secondary feedback F_2 originates at the sensors in muscles, tendons, joints, surface tissue, etc., used to stiffen the body, to support it by propping against external surfaces, etc. The third feedback F_3 is external, in such that it provides information about the score actually exerted at the dynamometer primarily through vision (such as seeing a pointer on an instrument) or audition (such as through the voice of the experimenter, or sounds of the recording device).

The excitation signals E in the feedforward system, along the efferent pathways, are often monitored through electromyograms. While this is a viable approach, and instrumentation for this is available commercially, it requires the application of needle or surface sensors, partial disrobing of the subject, and rather extensive recording and analysis equipment. Furthermore, it obviously monitors only the feedforward signals stimulating muscular activities which, in turn modified according to the prevailing mechanical advantages, bring about the force or torque monitored at the dynamometer. Thus the EMG signal is not necessarily proportional to the score recorded at the dynamometer. Hence, EMG monitoring was not pursued in this research.

Of the feedback systems, monitoring of the first two types of feedback signals appears not to be feasible at the current state of the art. Action potentials monitored along afferent pathways are difficult to interpret, primarily because such signals cannot be identified with specific sensors in muscles, tendons, articulations, or the skin. This is largely due to the fact that nerve fibers usually join to bundles, and thus signals monitored along these bundles cannot be routinely associated with given sensors. The only feedback system that can be manipulated with ease is the third one, the external feedback through audition and vision.

The strength of contraction of a bundle of muscles is regulated by two classes of coding, triggered by signals along the efferent pathways. Depending upon the threshold requirements of the contraction to be effected, two types of alpha-motor neurons are excited to initiate the contraction of extrafusal fibers. For low threshold exertions, small alpha-motor neurons are stimulated first which activate slow twitch fibers. For stronger exertions, more such motor units are activated. For high threshold exertions, larger alpha-motor neurons for the triggering of fast twitch fibers are also recruited. Thus, one method of regulating strength exertion consists of "recruitment coding" regarding the activation of the type and number of muscle fibers to be involved.

A second method to regulate the muscle strength exertion is through "rate coding". Here, increasingly higher frequency signals along the efferent nerve pathways speed up the firing rate of the motor units with increasing tension.

According to this model, the regulation of a strength exertion requires a coordination of a complex feedforward and feedback system. If external feedback is excluded, a closed loop system is established that works as follows: depending upon the desired strength output a stereotypical executive program is called up in the central nervous system. For low level (submaximal) muscle contractions, a delicate balance between recruitment and rate coding must be maintained requiring extensive feedback about the actual status of contraction. For a maximal exertion, both rate and recruitment coding are used from the onset to the fullest extent, with feedback required only regarding whether or not full muscular contraction is being executed.

EXPERIMENTAL HYPOTHESES

According to the model of muscle strength regulation just discussed, two experimental hypotheses were tested in this research. For the case of excluded external feedback, these hypotheses are:

1. For a maximal muscular contraction, both rate and recruitment coding are used to the fullest extent, and all feedback channels will simply report whether full loading is achieved. Thus, buildup of a maximal force should be achieved quickly.
2. For a submaximal muscular contraction, a fine balance between complex feedforward and feedback signals must be maintained. This is likely to require more time for the formation (buildup phase) of the muscular contraction.

In addition, the experimental hypotheses can also be applied to the phase of maintained force exertion as required by the experimental regimen (Caldwell et al. 1974). Following earlier reports in the literature (Beck and Hettinger 1956; Rohmert and Sieber 1960) more variability during the phase of maintained force exertion should be expected at submaximum levels than at maximum levels. However, this assumption is somewhat questionable since, obviously, the Caldwell regimen could not be followed before its publication in 1974.

In fact, there is anecdotal evidence that earlier researchers used experimental procedures quite different from the one used in these experiments. However, in the interest of scientific rigor the following hypothesis should also be tested:

3. Maximal strength exertions can be repeated by subjects without external feedback with less variability than submaximal exertions.

EXPERIMENTAL METHOD

The experiments to test the hypotheses were performed during 1979 in the Ergonomics Research Laboratories at Wayne State University. The experimental chamber used was an air conditioned room of approximately 4 by 5 meters.

Subjects and Procedures

Twenty female and twenty male subjects participated in the experiments. They were recruited from the Wayne State University population and were paid a fixed amount for their participation. While no attempts were made to select specific persons, it was clear to them that they would be required to exert muscular strength contractions with their arms, hands and legs. Thus, no persons obviously unable to perform such exertions volunteered to participate.

Upon arrival in the laboratory, each subject underwent the following routine:

a) The subject received general information and instructions, regarding the nature and procedure of the experiments. (See Table A1 in the Appendix.) The subject then filled in a personal data form. (See Table A2 in the Appendix.) Finally, the subject was asked to read and sign a subject consent form. (See Table A3 in the Appendix.)

b) A series of anthropometric measurements was then taken on the subject. For these measurements, the subject took off the shoes, emptied heavy materials from the pockets, and rolled up sleeves and slack legs as needed. The results of these measurements are shown on Table 1. (For a detailed description of the measurements, see Table A4 in the Appendix.)

c) The subject then sat down on the experimental chair and tried out each of the exertions to be performed with finger, arm and leg once in order to get a "feel" for the experiments.

d) Detailed instructions for the exertions were then read to the subject from a prepared text. (See Table A5 in the Appendix.) This was explained further by discussing as necessary the procedure of strength exertion as per the standardized regimen (Caldwell et al. 1974). In particular it was pointed out that there was no prescribed time during which the force buildup had to take place, but that this was usually accomplished within a time of about two seconds. (Table A6 in the Appendix indicates the countdown by the experimenter during the experiments.)

e) When subject and experimenter were satisfied that all instructions were clearly understood, the tests were performed. The sequence of trials was counterbalanced to control for carryover effects of training on the experimental results. In particular, the sequence was so arranged as to alternate between arm, finger and leg exertions. The minimum rest time between exertions was two minutes. The subject was encouraged to indicate any occurances of discomfort and fatigue freely. Throughout the tests, the experimenter would occasionally inquire about possible discomfort and fatigue in order to make sure that no such occurances would affect the results. All testing was completed within a period of about 100 minutes.

Variable	Minimum	Maxmimum	Mean	Std.Dev.
Age (years)	17.0	39.0	22.90	4.1989
Weight (lb)	106.0	230.0	147.27	28.3200
Stature (cm)	75.9	190.1	167.11	17.3350
Buttock-Knee Length (cm)	54.1	66.7	59.29	3.2106
Knee Height, sitting (cm)	46.5	58.7	52.91	2.8737
Shoulder-Elbow Length (cm)	29.3	41.4	33.92	2.4845
Forearm-Hand Length (cm)	38.4	51.4	45.32	3.1055
Hand Length (cm)	15.7	20.4	18.28	1.1678
Digit 2 Height (cm)	15.0	19.1	16.85	1.2043
Crotch 2 Height (cm)	8.9	11.7	10.18	.7577
Digit 2 Length (cm)	6.2	15.6	7.29	1.4271
Hand Breadth (cm)	5.3	10.1	7.98	.9649
Hand Thickness (cm)	2.2	3.6	2.96	.3507
Biceps Circ., flexed (cm)	22.2	36.4	29.72	3.5866
Biceps Circ., relaxed (cm)	21.3	35.6	28.56	3.4641
Forearm Circ., flexed (cm)	21.2	33.1	26.82	2.8321
Foreman Circ., relax (cm)	20.9	32.4	25.95	2.7451
Wrist Circ. (cm)	13.5	18.7	16.12	1.3720
Lower Thigh Circ. (cm)	28.9	42.5	37.42	2.7872
Knee Circ., standing (cm)	22.7	41.2	35.89	3.2581
Calf Circ., standing (cm)	30.0	43.2	36.12	2.9379
Ankle Circ., stand. (cm)	19.9	31.6	24.82	2.0597
Lever Arm (cm)	22.3	38.6	25.97	2.9095
Lever Leg (cm)	33.5	44.1	37.30	2.1260

Table 1 Descriptive Statistics of the Experimental Subjects (20 male, 20 female)

Apparatus

The experimental apparatus consisted primarily of a special chair, cuffs connecting the subject's arm or leg with dynamometers (load cells), and a strip chart recorder.

The chair had a horizontal sitting surface, about 57cm high and 38cm deep, and a vertical straight back 66cm high above the seat pan, each 56cm wide. On the right side was a rigid arm rest which extended horizontally 23cm from the back rest forward. The height of the arm rest could be varied between 20 and 30cm above the sitting surface. Its surface was slightly padded. In front of the arm rest a Lebow load cell (model 3397) was bolted to the seat. A wrist cuff was connected to this load cell. The subject propped the elbow of the right arm on the arm rest, extended the forearm directly forward so that the cuff was exactly above the load cell, with the edge of the cuff at the wrist crease. The elbow angle was approximately 90°.

A similar arrangement was provided for the knee extension and flexion experiments. Here a Lebow load cell (model 6431-102) was so arranged and connected by cables to the leg cuff that the subject had the cuff with its distal edge at a comfortable distance (about 2cm) above the ankle of the right leg. With the thigh resting on the sitting surface, the lower leg hang down vertically, with the foot not supported. The knee angle was approximately 90°.

For the finger flexion exertions, the subject put the right hand with the palm flatly on a horizontal surface which was slightly above elbow height. The tip of the extended forefinger was placed on a dynamometer in such a way that the tip of the finger extended 1cm onto the flat surface of the measuring device. While the experimenter pressed down slightly on the wrist of the subject in order to insure that the ball of the hand was not lifted from the surface, the subject pressed on the measuring device. The force was sensed by an Lebow load cell (model 10445). Forearm, palm and fingers were extended horizontally.

The cuffs used for the arm and leg force measurements were specially designed from steel hinges (1½ in. x 3/4 in.) welded together so that a cuff band of 3.8cm width resulted that was flexible at every .7cm. By adding or removing sections, a tight but comfortable fit could be achieved for every subject's wrist or ankle circumference. The insides of the cuffs were slightly padded.

These devices for the measurement of arm, leg and finger forces were designed not to give under the exertion of force, and thus to bring about an isometric muscle strength exertion.

The output of the load cells was recorded on a Gould Brush eight channel strip chart recorder (model 480). The deflections of the writing pens were calibrated in pounds before each experiment and checked appropriately. After each test, the experimenter checked the analog records for adherence to the requirements of the standard regimen (Caldwell et al. 1974). After all tests were completed, the experimenter marked the slopes of the force buildup and the maintained force levels through straight lines on the records, and read the values for slope (i.e. the angle of increase in terms of force units per time units) and for maintained force level (in terms of pounds). The data were then read into a computer and subjected to appropriate statistical analyses.

The subject was not informed about the scores achieved until all experiments were completed.

STATISTICAL TREATMENT OF THE DATA

Each subject was asked to exert force at four different levels, called 100%, 75%, 50% and 25% of his/her strength capability. Since three repetitions were performed at each of these levels, four different analogue recordings per subject were obtained at each level. They are shown schematically in Figure 2.

While the use of the onset slopes is straight forward, the data describing each subject's performance at the four requested levels were subjected to some conversion. In order to facilitate data reduction, and comparison of the results of different subjects, the raw data inputs were first converted into normalized data, using a percent notation. This procedure was performed in four steps:

(A) Step 1 - The average maintained force at the 100% level was calculated. This established the "base" for the following conversions.

Step 2 - Each recorded maintained force was converted into percent of the "base" force.

Step 3 - Within each requested level, the average force was calculated. (At the 100% level, this coincides with Step 1.)

Step 4 - Within each level, the absolute deviations from the level average were computed. These deviations were used for the variability analysis (ANOVA).

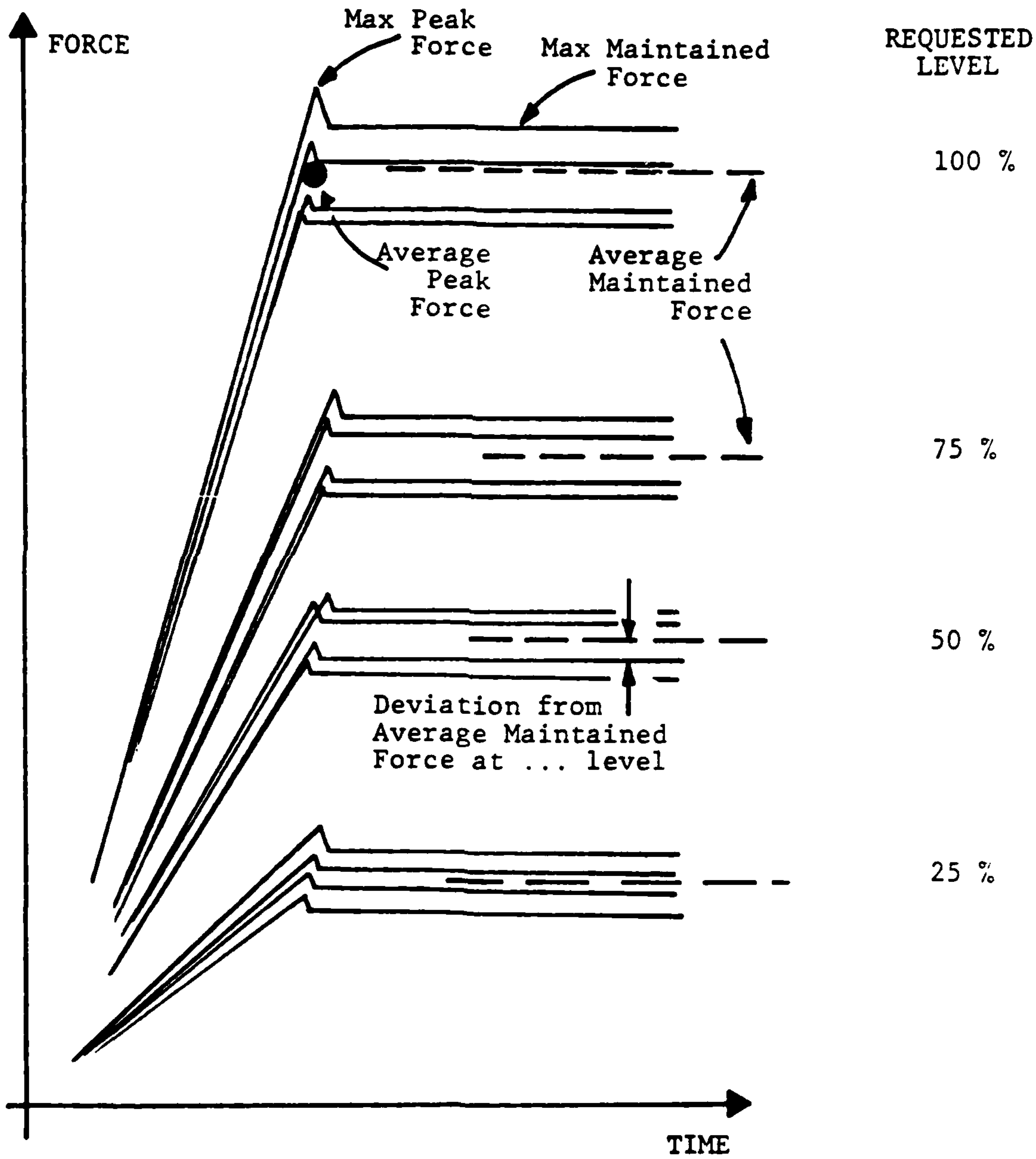

Figure 2: Bases for Statistical Treatment of the Experimental Data

(B) Furthermore, instead of using the average maintained force as "base" in Step 1, the maximal observed maintained force level was used as base. The steps 2 through 4 were then performed using this base value.

While (A) and (B) rely on the maintained forces as base data, the results were also analyzed with the peak values used as basic units. Thus, steps 1 through 4 were also performed using either the

(C) "average peak", or

(D) "maximal peak".

Procedures A, B, C and D allowed an analysis of the variability of the forces at each level, by ANOVA.

For each trial and subject, the correlation coefficients between onset slope and maximal maintained force -see B- and maximal peak force -see D- were also computed.

RESULTS

Tables 2 through 33 summarize the experimental results. They are presented in the following order:

(A) Group Behavior, based on the mean values of the raw data.

(B) Variability Analysis, based on the differences of each individual exertion from the average of repeated exertions (at each of the four repeated force levels - see "Statistical Treatment").

(C) Slope-Strength Analysis, relating each individual's build-up slope of strength formation to the maintained force level, or peak force.

Within each of these, the data for

Leg Flexion	(LF)
Leg Extension	(LE)
Elbow Flexion	(EF) and
Finger Flexion	(FF)

are reported separately, in that order.

(A) Group Behavior

The mean (over trials) maintained level and peak exertions (in pounds) as well as the slopes (in force per unit time) for each subject were calculated for the leg flexion (LF), leg extension (LE), elbow flexion (EF) and finger flexion (FF). These results appear in Tables 2 through 5. They contain group mean and standard deviation for each of these measures, as well as the mean and standard deviation for the two sexes. Males exhibited more force, and did so faster at each strength exertion level under all types of force exertions, than did females.

These data were converted into the percentage of force for each subject in order to normalize the data. The resulting group and sex means and standard deviations, calculated for LF, LE, EF and FF, appear in Tables 6 through 9. For the LF, LE and EF types of exertion, females tended to exert a greater percentage of their strength at each exertion level than did males, but males exerted a larger portion in the FF types of exertion.

Finally, the percent difference from the subject's exertion level mean was calculated according to the method described in the "Statistical Treatment" section. These statistics for the whole group as well as for each sex at each level for LF, LE, EF and FF appear in Tables 10 through 13. No clear trend appeas with respect to sex or exertion level.

LEG FLEXION

MEANS OF RAW DATA, ALL SUBJECTS

SUBJECT	SLOPE 100%	SLOPE 75%	SLOPE 50%	SLOPE 25%	MAINTAIN STRENGTH 100%	MAINTAIN STRENGTH 75%	MAINTAIN STRENGTH 50%	MAINTAIN STRENGTH 25%	PEAK 100%	PEAK 75%	PEAK 50%	PEAK 25%
1	379.77	217.82	144.87	82.59	61.75	54.00	48.00	30.25	62.75	54.75	49.25	30.50
2	49.28	18.02	22.78	12.22	24.47	12.47	13.94	7.34	25.39	13.54	14.64	8.09
3	212.29	48.19	31.50	16.17	45.50	24.75	19.25	7.00	47.00	26.00	19.50	7.50
4	61.72	40.39	41.02	32.52	37.50	26.75	24.00	12.00	39.50	27.00	24.00	13.00
5	130.72	143.02	61.73	53.39	48.75	42.09	32.75	26.00	50.42	43.79	33.54	26.84
6	29.52	20.74	11.89	5.61	17.07	14.54	9.64	5.72	17.94	15.19	10.44	6.12
7	204.84	72.22	62.17	43.19	61.50	46.50	38.00	25.75	63.00	47.50	38.67	25.75
8	29.48	18.59	9.30	12.28	11.77	10.25	7.32	5.29	12.02	10.39	7.62	5.75
9	171.58	40.77	26.94	25.63	31.62	23.00	17.25	11.12	32.37	24.25	17.72	11.75
10	27.14	17.69	15.14	14.92	27.75	17.87	14.52	13.87	28.39	18.62	15.17	14.42
11	61.39	31.84	25.35	22.87	35.12	20.25	17.12	14.75	36.07	20.62	17.50	15.25
12	12.00	4.61	2.93	3.13	8.75	2.58	1.72	1.54	8.77	2.62	1.79	1.61
13	134.50	55.37	41.03	33.84	33.67	22.25	22.82	18.14	34.25	22.69	23.25	18.72
14	131.28	70.39	43.75	21.41	37.94	29.14	21.27	13.39	38.59	30.12	21.64	13.62
15	251.17	126.00	139.94	61.94	50.50	37.25	29.00	19.25	54.25	38.50	29.25	19.75
16	38.54	48.59	22.79	15.50	15.00	9.12	7.75	3.75	15.00	9.37	7.87	3.87
17	306.54	85.46	38.11	39.27	69.00	43.50	25.82	14.69	70.62	44.37	27.17	15.17
18	25.39	21.31	16.68	5.75	23.50	15.25	11.75	5.75	24.29	15.62	12.50	6.07
19	44.00	28.34	30.11	26.63	45.54	27.54	36.64	32.25	46.39	28.64	37.50	32.84
20	32.94	15.89	17.14	12.39	28.12	15.62	14.75	11.50	29.62	15.75	15.50	11.50
21	44.42	28.30	20.10	16.17	43.02	30.39	23.89	19.14	43.67	30.87	24.50	19.59
22	21.00	13.52	11.45	12.78	10.02	7.22	6.34	6.72	10.12	7.54	6.50	6.84
23	26.36	13.50	6.56	10.23	17.72	10.42	6.94	6.44	18.54	11.17	7.04	6.94
24	18.67	32.32	8.00	16.57	18.79	14.19	6.19	5.02	19.27	14.54	6.25	5.25
25	52.50	16.37	10.02	8.59	20.62	13.94	7.54	6.82	21.14	14.12	7.64	6.97
26	56.31	34.23	30.58	29.33	32.04	22.19	19.72	15.75	32.29	22.54	20.12	15.97
27	35.50	15.12	14.59	12.04	36.75	20.00	16.44	11.75	38.79	20.64	16.62	11.75
28	39.64	27.22	19.22	21.52	38.00	28.50	22.75	18.75	38.75	29.25	23.00	19.14
29	34.61	27.32	23.88	12.72	26.79	9.02	8.47	6.09	30.67	9.17	9.89	6.27
30	21.50	13.30	12.66	10.26	21.32	16.07	11.47	8.14	21.75	16.34	11.72	8.32
31	69.22	54.17	30.70	26.07	51.19	36.07	30.87	19.19	52.19	36.79	31.47	19.44
32	24.77	15.01	11.87	7.37	17.22	12.27	10.75	7.82	17.72	12.79	11.09	7.94
33	197.91	71.04	18.97	31.52	44.09	16.19	10.32	8.34	45.84	16.89	10.62	9.00
34	28.73	18.59	12.45	11.05	28.12	16.75	9.29	6.92	29.17	17.69	9.44	7.25
35	520.83	150.29	98.57	37.57	48.62	25.14	17.42	13.00	49.87	26.12	17.84	13.34
36	16.01	15.58	9.44	12.75	14.07	10.69	8.87	7.77	14.42	10.79	9.02	7.97
37	52.97	17.27	17.96	12.19	24.97	11.25	9.64	6.39	25.59	11.34	9.79	6.44
38	54.19	24.38	27.12	9.01	16.75	12.50	9.64	6.94	17.47	13.14	10.00	7.04
39	49.55	22.93	14.71	5.37	36.87	23.22	14.72	5.29	37.27	24.64	15.02	5.52
40	27.31	17.61	17.74	8.12	22.52	14.22	11.42	7.00	24.27	15.17	13.57	7.04
MEAN	93.15	43.83	30.54	21.31	32.10	21.12	16.89	11.81	33.13	21.77	17.39	12.15
STANDARD DEVIATION	109.61	44.17	31.21	16.51	14.88	11.50	10.04	7.30	15.27	11.74	10.19	7.37
Female MEAN	37.27	24.39	18.19	13.72	22.53	15.40	12.15	8.54	23.23	15.90	12.59	8.83
Female STANDARD DEVIATION	25.39	14.52	10.35	7.38	8.89	6.58	5.76	4.20	9.20	6.81	5.81	4.27
Male MEAN	149.03	63.26	42.88	28.89	41.67	26.83	21.64	15.08	43.03	27.64	22.18	15.46
Male STANDARD DEVIATION	130.91	54.18	39.20	19.38	13.45	12.44	11.11	8.23	13.64	12.66	11.32	8.28

Table 2 - Raw Data for Slope, Maintained Level, and Peak Exertions for Leg Flexion

LEG EXTENSION

MEANS OF RAW DATA, ALL SUBJECTS

SUBJECT	SLOPE 100%	SLOPE 75%	SLOPE 50%	SLOPE 25%	MAINTAIN STRENGTH 100%	MAINTAIN STRENGTH 75%	MAINTAIN STRENGTH 50%	MAINTAIN STRENGTH 25%	PEAK 100%	PEAK 75%	PEAK 50%	PEAK 25%
1	186.89	163.44	127.07	113.19	64.25	44.75	40.50	36.75	66.00	47.50	42.00	38.25
2	54.66	25.70	31.12	32.79	34.79	15.32	17.04	15.39	35.84	15.54	17.64	15.69
3	329.94	81.52	120.82	32.29	70.25	48.50	34.50	14.50	75.50	50.25	36.50	15.25
4	77.64	198.62	51.64	41.79	57.00	38.00	32.50	18.00	60.50	38.50	33.50	18.00
5	107.14	62.27	60.15	58.11	59.50	39.04	28.75	23.19	61.79	40.09	30.00	23.82
6	45.74	45.49	77.23	20.13	40.79	28.37	13.25	9.39	41.54	29.00	13.44	9.67
7	162.50	141.67	88.19	76.59	73.50	52.50	36.50	25.00	78.00	55.00	37.25	25.50
8	34.17	23.45	17.14	16.12	17.25	10.25	7.29	6.12	18.39	10.62	7.67	6.42
9	280.55	137.50	63.12	54.58	52.75	41.87	35.75	22.75	53.87	42.92	37.37	23.25
10	50.44	37.12	21.75	16.09	37.75	33.50	16.25	14.25	42.37	35.25	17.02	14.75
11	49.25	36.39	31.95	15.81	44.37	22.87	16.19	11.75	46.00	24.00	17.07	12.17
12	19.55	5.60	4.76	2.62	14.07	3.39	2.19	1.09	14.25	3.48	2.32	1.17
13	94.44	59.29	49.09	28.80	45.94	28.94	22.75	15.22	47.25	30.54	23.59	16.14
14	100.69	62.70	38.06	34.61	48.00	29.09	23.14	10.69	48.32	30.00	23.79	11.84
15	572.92	262.50	251.17	94.07	77.25	60.75	48.50	32.00	79.25	62.00	49.00	33.50
16	39.34	48.79	28.72	24.79	17.50	11.00	7.50	5.12	17.50	11.50	7.75	5.50
17	295.45	117.26	53.04	40.50	62.00	28.87	23.00	13.52	65.87	29.92	24.32	14.07
18	26.73	35.71	14.36	11.10	24.75	15.25	8.09	4.50	27.32	16.17	9.89	5.37
19	35.72	25.16	16.89	23.94	36.64	25.54	21.25	24.50	41.27	29.04	22.29	27.44
20	52.34	24.34	13.64	33.72	46.75	20.87	15.62	13.87	48.37	21.75	16.12	14.00
21	40.34	53.33	28.35	13.29	47.47	37.79	24.64	14.00	48.94	38.54	26.09	14.57
22	31.90	17.23	22.75	14.51	19.62	10.32	10.07	6.44	19.97	10.47	10.59	6.77
23	84.72	16.16	21.37	10.20	38.75	16.00	10.72	5.87	40.14	16.52	11.22	6.75
24	43.56	28.24	19.07	13.99	26.79	16.44	8.92	6.27	28.29	16.84	9.72	7.02
25	53.35	10.30	13.14	8.72	37.39	12.25	9.72	6.27	38.22	12.75	10.12	6.64
26	76.38	42.46	40.30	37.04	54.62	28.52	26.37	21.27	55.89	29.79	28.09	22.75
27	36.34	18.17	11.67	9.00	41.62	21.00	13.25	8.37	45.62	21.54	13.87	9.00
28	65.22	48.87	45.75	34.09	51.75	36.50	31.62	24.50	53.50	37.25	32.39	25.00
29	132.14	77.08	69.35	47.16	76.00	42.50	30.37	20.02	78.25	44.69	33.62	21.59
30	26.51	22.08	20.65	16.59	18.00	14.82	10.50	6.57	18.62	15.29	11.34	6.75
31	96.78	65.20	58.67	46.60	71.87	51.87	40.92	31.37	72.37	52.44	41.94	32.22
32	34.94	26.17	17.53	13.63	20.79	17.89	10.47	7.75	21.79	21.59	11.29	8.32
33	288.09	70.40	62.04	48.82	85.25	25.84	19.47	16.69	87.39	26.75	20.09	17.94
34	52.78	29.08	22.60	16.03	42.94	20.67	15.82	8.72	44.14	21.34	16.57	9.79
35	1250.00	328.12	283.33	98.21	116.29	35.87	27.02	14.69	121.00	37.44	28.07	15.52
36	32.51	16.76	10.33	9.25	22.07	13.87	9.57	7.34	22.79	14.42	9.97	8.09
37	87.29	65.11	47.39	22.86	42.07	26.04	18.69	9.07	42.29	26.94	19.00	9.34
38	92.01	35.68	24.98	24.00	22.19	14.47	11.62	5.67	22.77	15.34	12.22	5.77
39	73.75	41.14	18.22	13.92	41.87	27.97	14.00	6.77	43.17	29.07	15.89	7.69
40	45.42	24.30	19.99	26.09	34.25	18.37	17.00	9.50	35.87	19.62	18.04	11.02
MEAN	131.50	65.75	50.43	32.39	45.91	27.19	20.28	13.86	47.75	28.29	21.21	14.60
STANDARD DEVIATION	137.36	68.04	57.12	25.32	21.67	13.34	10.92	8.37	22.44	13.69	11.18	8.63
Female MEAN	50.12	39.91	27.11	21.94	32.58	19.84	14.74	10.12	33.90	20.68	15.46	10.68
Female STANDARD DEVIATION	21.66	38.66	16.30	10.46	13.66	9.24	7.94	5.84	14.18	9.46	8.11	5.93
Male MEAN	212.87	91.59	73.75	42.83	59.25	34.53	25.82	17.61	61.60	35.09	26.96	18.53
Male STANDARD DEVIATION	155.00	80.25	71.93	30.90	19.93	12.75	10.68	8.82	20.56	13.02	10.88	9.11

Table 3 - Raw Data for Slope, Maintained Level, and Peak Exertions for Leg Extention

Elbow Flexion

MEANS OF RAW DATA, ALL SUBJECTS

	SLOPE				MAINTAIN STRENGTH				PEAK			
SUBJECT	100%	75%	50%	25%	100%	75%	50%	25%	100%	75%	50%	25%
1	301.37	227.54	145.82	74.77	109.50	78.75	59.00	33.25	118.00	92.00	65.75	36.00
2	99.11	53.78	85.89	46.05	33.19	17.64	18.09	10.14	38.00	24.39	25.07	16.69
3	291.64	141.27	67.37	36.27	81.25	40.50	23.25	7.50	85.00	47.37	26.00	8.87
4	187.52	70.12	109.00	47.39	44.25	28.87	21.87	12.87	48.75	34.62	27.75	19.37
5	326.18	177.62	135.33	78.04	92.34	58.87	44.75	34.32	106.69	75.59	57.67	40.62
6	72.02	51.92	28.53	19.55	28.52	12.77	8.12	4.07	35.47	19.50	11.02	7.59
7	458.32	202.37	117.27	92.37	103.00	68.50	40.50	26.25	106.75	77.00	50.25	33.00
8	57.25	38.18	30.16	19.28	20.57	13.57	10.29	6.79	26.32	18.34	12.89	9.00
9	299.60	227.37	213.68	106.86	77.69	30.62	28.04	23.02	90.14	52.57	52.37	33.54
10	64.72	38.77	42.04	14.80	30.69	22.69	14.17	6.87	41.12	25.12	19.29	8.62
11	100.35	51.11	41.80	33.65	59.22	27.29	22.04	18.92	65.42	31.04	25.54	21.09
12	76.84	16.95	17.91	8.40	26.75	5.14	3.89	2.67	31.59	6.02	5.19	3.52
13	258.92	92.66	84.14	51.23	73.52	29.82	27.29	17.72	75.39	39.84	34.59	20.69
14	194.22	68.68	60.24	31.43	48.82	25.54	23.92	12.37	52.25	40.72	32.22	15.00
15	458.32	194.44	188.14	124.27	92.00	43.25	41.75	30.75	97.75	55.50	50.50	36.75
16	69.44	57.79	58.32	27.12	22.25	12.25	11.12	5.12	25.00	16.00	15.50	7.75
17	600.00	183.33	90.73	53.30	89.69	42.32	18.67	8.62	95.42	57.17	30.92	16.07
18	43.43	22.15	12.19	11.78	42.07	15.67	8.57	4.87	45.12	18.02	9.67	6.00
19	69.37	47.16	35.19	32.73	61.39	27.84	23.00	18.62	69.75	36.32	34.09	25.25
20	50.94	28.07	19.17	14.62	43.12	24.75	14.87	11.37	45.00	27.62	15.67	11.87
21	152.38	45.35	29.01	21.52	91.27	36.94	27.09	21.42	95.62	39.97	[illegible]	23.37
22	27.22	17.27	15.40	14.47	14.25	5.54	5.32	3.94	15.39	6.97	6.69	4.94
23	210.71	57.49	46.61	27.90	58.84	27.57	21.37	11.75	71.62	31.37	25.79	16.34
24	42.75	20.38	17.25	11.74	19.42	10.42	5.92	2.84	22.09	11.92	8.62	4.29
25	54.49	50.68	23.79	15.58	49.64	16.09	11.89	6.67	56.22	20.52	13.84	8.39
26	118.05	63.24	33.88	32.16	41.64	18.42	13.19	8.97	43.32	24.04	18.12	12.54
27	212.79	53.89	44.62	26.79	89.25	43.50	29.50	22.50	92.25	49.69	38.62	26.54
28	83.32	43.57	42.02	32.39	44.50	29.75	29.75	18.87	47.50	32.37	33.62	21.75
29	222.22	97.63	85.22	39.89	67.94	34.25	24.32	14.29	73.25	46.75	38.14	18.59
30	111.45	47.93	45.43	25.38	28.50	15.57	11.27	8.25	31.69	20.77	14.89	10.37
31	153.50	113.11	66.15	58.95	60.94	49.52	39.42	27.94	68.25	61.09	44.44	36.39
32	43.97	47.91	25.29	22.45	26.72	15.92	10.97	7.32	30.00	23.14	16.32	11.27
33	343.05	125.00	34.74	23.40	81.84	27.50	13.57	8.64	87.82	38.47	18.79	10.37
34	78.59	34.64	42.74	26.70	44.42	25.17	20.87	13.27	49.62	29.02	24.72	15.02
35	500.00	333.33	93.40	82.19	70.87	32.19	16.50	11.07	74.04	47.97	23.04	18.39
36	62.50	22.00	17.49	13.42	19.89	8.54	5.92	5.37	27.44	12.19	9.57	7.87
37	170.45	60.89	71.13	34.08	38.00	17.94	15.89	10.04	41.47	20.25	17.27	11.84
38	177.08	76.38	69.36	44.90	29.82	18.69	14.67	9.25	41.50	27.39	22.00	12.42
39	245.83	57.33	38.83	15.15	59.34	23.59	18.97	7.14	63.00	30.67	22.37	9.44
40	53.21	25.76	18.88	11.57	24.19	11.75	7.50	5.34	30.12	18.69	11.32	7.14
MEAN	179.57	84.62	61.10	37.61	53.52	27.23	20.17	13.02	59.02	34.69	26.11	16.61
STANDARD DEVIATION	140.42	71.35	46.27	27.17	26.31	16.00	11.96	8.53	27.15	19.19	14.62	9.98
Female MEAN	85.68	42.27	39.55	23.77	31.67	16.93	13.01	8.02	36.36	21.84	17.00	10.65
STANDARD DEVIATION	47.86	18.34	25.26	11.82	10.13	7.11	6.73	4.05	10.08	8.69	8.05	4.86
Male MEAN	273.47	126.97	82.64	51.44	75.37	37.54	27.33	18.02	81.69	47.55	35.21	22.57
STANDARD DEVIATION	139.68	79.11	52.11	30.89	18.10	15.78	11.76	8.89	18.59	18.19	14.04	10.23

Table 4 - Raw Data for Slope, Maintained Level, and Peak Exertions for Elbow Flexion

Finger Flexion

MEANS OF RAW DATA, ALL SUBJECTS

SUBJECT	SLOPE 100%	SLOPE 75%	SLOPE 50%	SLOPE 25%	MAINTAIN STRENGTH 100%	MAINTAIN STRENGTH 75%	MAINTAIN STRENGTH 50%	MAINTAIN STRENGTH 25%	PEAK 100%	PEAK 75%	PEAK 50%	PEAK 25%
1	38.61	16.48	19.60	12.92	11.12	7.50	8.37	4.87	12.37	9.62	10.50	5.50
2	18.96	12.05	7.46	5.06	3.75	2.52	1.75	1.12	4.82	3.27	2.34	1.54
3	33.34	20.37	70.52	7.69	6.94	4.64	2.69	1.00	7.64	5.27	3.27	1.34
4	30.52	13.84	13.50	6.79	6.77	4.64	2.62	1.14	7.44	5.59	3.84	2.19
5	35.41	37.88	23.93	18.66	11.07	8.08	7.21	7.06	12.64	11.47	9.34	8.89
6	20.03	4.77	2.57	1.25	3.12	2.04	0.87	0.69	4.02	2.54	0.94	0.84
7	122.92	75.12	61.69	24.19	18.50	13.50	8.62	4.87	20.50	15.25	11.50	6.75
8	7.86	4.27	2.64	1.19	2.22	C.97	0.40	0.25	2.60	1.19	0.61	0.29
9	63.44	35.01	15.04	23.98	7.89	5.07	3.17	3.19	10.04	7.64	5.29	3.79
10	14.79	2.64	4.50	1.35	6.19	2.08	1.31	0.55	6.59	2.31	1.56	0.64
11	15.53	7.14	7.00	3.57	5.42	3.02	2.19	1.44	6.87	3.52	2.62	1.57
12	15.09	3.21	1.23	0.85	4.23	1.10	0.52	0.21	5.86	1.34	0.67	0.33
13	29.58	20.09	17.55	13.39	7.97	4.50	3.52	3.36	9.42	7.06	5.18	4.68
14	33.03	15.78	10.04	9.70	6.40	3.75	3.30	2.15	7.45	5.67	4.10	3.16
15	45.82	21.07	18.04	12.69	10.39	4.44	3.52	2.64	11.19	5.59	4.09	3.00
16	14.00	9.09	7.50	3.79	4.07	2.32	2.04	0.59	4.57	2.69	2.79	0.79
17	57.61	20.68	15.59	7.65	9.64	4.26	1.91	0.73	11.39	6.10	3.59	1.50
18	7.21	2.50	2.10	1.55	5.29	1.91	1.37	0.63	5.90	2.39	1.61	0.82
19	8.39	4.35	6.70	3.68	6.06	4.26	4.21	2.98	7.53	4.91	5.29	3.53
20	6.34	3.19	2.22	1.62	5.02	2.39	1.52	1.29	5.34	2.59	1.69	1.68
21	12.78	6.00	5.18	2.67	8.27	5.08	4.31	1.97	9.24	5.55	4.74	2.34
22	7.14	5.59	4.16	3.86	1.97	0.87	0.96	0.64	2.33	1.33	0.94	0.74
23	15.47	4.22	1.12	1.16	4.32	1.54	0.87	0.59	5.17	1.89	1.00	0.69
24	11.57	3.64	5.10	0.93	2.75	1.25	0.78	0.20	3.33	1.66	1.35	0.33
25	18.48	9.35	8.19	3.06	8.01	3.53	2.55	1.11	8.83	4.15	3.26	1.50
26	24.14	4.09	3.55	1.03	4.37	1.44	0.95	0.32	5.92	1.83	1.47	0.51
27	13.12	6.44	5.02	3.09	11.32	4.69	3.94	1.84	12.37	5.54	4.42	2.02
28	13.27	8.09	6.00	2.75	6.79	3.97	2.37	1.18	7.82	4.57	2.97	1.47
29	36.17	27.91	14.78	10.29	11.45	5.45	3.53	2.11	12.37	6.97	4.29	2.34
30	11.11	6.65	5.19	2.71	3.48	2.36	1.46	1.00	4.48	2.98	1.85	1.11
31	14.32	10.92	7.55	3.81	6.12	4.84	3.11	1.69	7.67	5.72	4.05	2.19
32	11.78	6.18	4.26	1.30	4.01	2.13	1.75	0.85	5.04	2.70	2.13	0.98
33	49.64	9.44	5.97	2.29	6.63	2.46	1.42	0.39	8.80	3.06	2.02	0.64
34	11.42	3.79	7.36	2.13	5.95	2.37	1.71	0.64	6.61	2.81	2.39	0.76
35	54.16	30.83	18.75	4.88	8.87	3.12	2.13	0.33	10.26	4.65	3.31	0.52
36	12.40	4.58	2.61	1.90	3.55	1.51	1.28	0.66	5.49	2.10	1.42	0.85
37	10.64	C.47	3.02	3.46	3.06	1.39	1.14	0.44	3.34	1.62	1.29	0.66
38	8.81	1.69	1.46	1.25	2.33	0.67	0.42	0.26	2.70	0.83	0.55	0.45
39	18.83	2.48	2.55	0.93	5.33	1.02	0.76	0.43	7.02	1.33	1.04	0.50
40	11.36	2.40	2.12	1.27	5.19	1.72	1.37	0.35	5.70	1.89	1.59	0.56
MEAN	24.62	12.20	10.58	5.40	6.39	3.35	2.44	1.44	7.46	4.22	3.17	1.84
STANDARD DEVIATION	21.74	13.70	14.04	5.94	3.27	2.38	1.92	1.47	3.52	2.96	2.49	1.84
Female MEAN	14.54	5.90	4.77	2.61	4.37	2.09	1.43	0.73	5.20	2.61	1.83	1.00
Female STANDARD DEVIATION	7.23	3.86	3.06	2.22	1.48	1.01	0.72	0.46	1.57	1.29	0.96	0.68
Male MEAN	34.71	18.51	16.38	8.20	8.41	4.61	3.45	2.15	9.73	5.84	4.50	2.69
Male STANDARD DEVIATION	26.25	16.77	17.83	7.08	3.31	2.68	2.20	1.76	3.48	3.26	2.82	2.20

Table 5 - Raw Data for Slope, Maintained Level, and Peak Exertions for Finger Flexion

Leg Flexion

MEANS OF PERCENT, ALL SUBJECTS

SUBJECT	SLOPE 100%	SLOPE 75%	SLOPE 50%	SLOPE 25%	MAINTAIN STRENGTH 100%	MAINTAIN STRENGTH 75%	MAINTAIN STRENGTH 50%	MAINTAIN STRENGTH 25%	PEAK 100%	PEAK 75%	PEAK 50%	PEAK 25%
1	99.99	57.34	38.14	21.74	99.99	87.44	77.72	48.98	99.99	87.24	78.47	48.59
2	100.01	36.57	46.22	24.79	100.01	50.97	57.00	30.03	100.03	53.36	57.69	31.89
3	100.00	22.69	14.83	7.61	99.99	54.38	42.30	15.37	99.99	55.31	41.48	15.95
4	100.00	65.45	66.46	52.69	99.99	71.32	63.99	31.99	99.99	68.34	60.75	32.90
5	100.00	109.40	47.22	40.84	99.99	86.35	67.17	53.32	100.00	86.86	66.53	53.25
6	100.00	70.27	40.28	19.09	100.02	85.23	56.52	33.53	100.04	84.72	58.24	34.13
7	100.00	35.25	30.34	21.08	99.99	75.60	61.78	41.86	99.99	75.39	61.38	40.86
8	100.01	63.06	31.56	41.65	100.03	87.08	62.22	45.02	100.03	86.51	63.43	47.82
9	100.00	23.76	15.69	14.93	100.00	72.73	54.54	35.17	100.01	74.90	54.75	36.29
10	100.03	65.21	55.81	54.98	99.99	64.40	52.33	49.99	100.02	65.59	53.44	50.80
11	100.00	51.86	41.29	37.26	100.00	57.65	48.75	41.99	100.00	57.17	48.51	42.27
12	100.01	38.49	24.43	26.14	99.99	29.56	19.70	17.70	100.05	29.92	20.51	18.38
13	99.99	41.16	30.50	25.16	100.00	66.07	67.78	53.90	99.99	66.27	67.87	54.66
14	100.00	53.61	33.31	16.30	100.02	76.82	56.06	35.31	100.02	78.05	56.09	35.29
15	59.99	50.15	55.71	24.65	99.99	73.75	57.41	38.11	99.99	70.96	53.90	36.39
16	100.01	126.09	59.15	40.21	99.99	60.82	51.66	24.99	99.99	62.49	52.49	25.82
17	99.99	27.87	12.43	12.80	99.99	63.03	37.42	21.29	100.00	62.82	38.47	21.48
18	100.02	83.94	65.72	22.64	99.99	64.88	49.99	24.46	100.03	64.32	51.45	25.00
19	100.00	64.41	68.42	60.53	100.01	60.49	80.47	70.80	100.01	61.75	80.83	70.80
20	100.02	48.26	52.05	37.63	100.01	55.55	52.44	40.85	100.01	53.16	52.32	38.81
21	100.00	63.72	45.25	36.40	100.00	70.65	55.54	44.50	100.00	70.69	56.09	44.87
22	59.99	64.39	54.56	60.88	100.04	72.10	63.37	67.11	100.04	74.59	64.22	67.67
23	100.02	51.23	24.92	38.81	100.02	58.82	39.21	36.39	100.04	60.26	38.01	37.47
24	100.04	173.14	42.88	88.78	100.04	75.56	32.98	26.73	100.01	75.50	32.42	27.23
25	100.00	31.18	19.08	16.36	100.01	67.64	36.60	33.09	100.04	66.80	36.18	32.98
26	100.00	60.79	54.30	52.09	100.02	69.28	61.55	49.14	100.02	69.82	62.31	49.46
27	99.99	42.59	41.12	33.93	99.99	54.41	44.75	31.96	100.02	53.22	42.85	30.28
28	100.02	68.67	48.49	54.29	99.99	74.99	59.86	49.33	99.99	75.47	59.34	49.41
29	100.02	78.93	69.00	36.76	100.03	33.68	31.62	22.76	100.01	29.90	32.27	20.45
30	100.04	61.88	58.91	47.73	100.01	75.39	53.81	38.22	99.99	75.16	53.90	38.26
31	100.00	78.26	44.35	37.66	100.01	70.46	60.30	37.50	100.01	70.50	60.30	37.26
32	100.03	60.61	47.93	29.78	100.02	71.27	62.42	45.43	100.02	72.22	62.63	44.85
33	100.00	35.88	9.58	15.92	100.01	36.73	23.41	18.93	100.01	36.86	23.17	19.62
34	100.00	64.73	43.33	38.47	100.01	59.56	33.06	24.62	100.00	60.67	32.38	24.84
35	99.99	28.85	18.92	7.20	100.00	51.72	35.83	26.73	100.00	52.37	35.78	26.76
36	100.02	97.37	59.00	79.62	100.02	76.04	63.07	55.25	100.02	74.89	62.57	55.29
37	100.00	32.61	33.90	23.01	100.01	45.04	38.63	25.62	100.03	44.34	38.29	25.19
38	99.99	44.99	50.05	16.62	99.99	74.62	57.60	41.48	100.01	75.26	57.23	40.34
39	100.00	46.28	29.69	10.85	100.00	62.98	39.93	14.36	100.00	66.13	40.30	14.81
40	100.01	64.48	64.97	29.73	100.01	63.15	50.72	31.07	100.01	62.52	55.92	29.04
MEAN	100.00	59.63	42.24	33.93	100.00	65.20	51.53	36.87	100.01	65.30	51.61	36.93
STANDARD DEVIATION	0.00	28.54	16.34	18.45	0.00	13.49	13.57	13.14	0.00	13.67	13.65	13.19
Female MEAN	100.01	70.59	49.96	41.70	100.00	67.92	53.01	38.11	100.01	68.12	53.46	38.36
STANDARD DEVIATION	0.00	30.51	11.28	19.51	0.00	12.52	11.41	12.06	0.00	12.38	11.39	12.06
Male MEAN	99.99	48.66	34.51	26.17	100.00	62.48	50.05	35.63	100.00	62.48	49.77	35.51
STANDARD DEVIATION	0.00	21.41	16.94	13.40	0.00	13.87	15.29	14.04	0.00	14.31	15.36	14.09

Table 6 - Exertion Components Converted to Mean Percentage of Strength at Each Exertion Level for Leg Flexion

Leg Extension

MEANS OF PERCENT, ALL SUBJECTS

SUBJECT	SLOPE 100%	SLOPE 75%	SLOPE 50%	SLOPE 25%	MAINTAIN STRENGTH 100%	MAINTAIN STRENGTH 75%	MAINTAIN STRENGTH 50%	MAINTAIN STRENGTH 25%	PEAK 100%	PEAK 75%	PEAK 50%	PEAK 25%
1	100.00	87.45	67.98	60.56	99.99	69.64	63.02	57.19	99.99	71.96	63.63	57.94
2	100.00	47.02	56.93	59.99	100.02	44.04	49.00	44.25	100.01	43.38	49.24	43.80
3	99.99	24.70	36.61	9.78	99.99	69.03	49.10	20.63	99.99	66.55	48.33	20.19
4	100.00	255.82	66.51	53.83	99.99	66.66	57.01	31.57	99.99	63.63	55.36	29.74
5	99.99	58.12	56.14	54.24	99.99	65.62	48.31	38.98	100.01	64.88	48.54	38.55
6	100.00	99.45	168.85	44.01	100.01	69.55	32.47	23.03	100.01	69.80	32.37	23.28
7	99.99	87.17	54.26	47.13	99.99	71.42	49.65	34.00	99.99	70.50	47.75	32.68
8	100.02	68.65	50.17	47.17	99.99	59.41	42.31	35.50	100.04	57.76	41.72	34.92
9	59.99	49.00	22.49	19.45	99.99	79.37	67.76	43.12	100.00	79.67	69.37	43.15
10	100.01	73.59	43.11	31.91	99.99	88.73	43.04	37.74	100.00	83.18	40.17	38.80
11	100.01	73.88	64.87	32.11	100.00	51.54	36.50	26.47	99.99	52.16	37.11	26.46
12	100.00	28.68	24.37	13.44	100.03	24.15	15.62	7.81	99.99	24.46	16.30	8.23
13	99.99	62.77	51.98	30.49	100.01	63.01	49.51	33.13	99.99	64.65	49.93	34.17
14	59.99	62.26	37.80	34.37	99.99	60.62	48.22	22.28	100.00	62.08	49.25	24.51
15	59.99	45.81	43.83	16.41	99.99	78.63	62.77	41.41	99.99	78.22	61.82	42.26
16	100.01	124.04	73.01	63.03	99.99	62.85	42.85	29.27	99.99	65.70	44.28	31.42
17	99.99	39.68	17.94	13.70	99.99	46.56	37.09	21.80	100.00	45.42	36.92	21.36
18	100.01	133.61	53.74	41.52	99.99	61.60	32.72	18.17	100.00	59.19	36.23	19.67
19	100.02	70.45	47.30	67.04	100.01	69.72	57.99	66.86	100.00	70.38	54.02	66.50
20	100.01	46.51	26.07	64.42	99.99	44.64	33.41	29.67	100.00	44.96	33.33	28.93
21	100.00	132.20	70.27	32.95	100.00	79.62	51.92	29.48	100.01	78.76	53.32	29.77
22	100.01	54.03	71.33	45.51	100.02	52.61	51.34	32.86	100.01	52.44	53.07	33.92
23	59.99	19.06	25.22	12.03	99.99	41.28	27.67	15.15	100.01	41.16	27.96	16.80
24	100.01	64.83	43.79	32.12	100.03	61.39	33.30	23.41	100.03	59.55	34.37	24.82
25	59.99	19.30	24.62	16.35	100.01	32.75	26.00	16.77	100.00	33.35	26.48	17.39
26	100.00	55.58	52.76	48.50	100.00	52.21	48.28	38.94	100.01	53.31	50.26	40.69
27	100.01	50.00	32.11	24.75	100.00	50.44	31.82	20.11	100.00	47.23	30.40	19.72
28	100.00	74.93	70.13	52.27	99.99	70.52	61.10	47.33	99.99	69.62	60.55	46.72
29	100.00	58.32	52.47	35.68	99.99	55.91	39.95	26.34	99.99	57.11	42.96	27.59
30	100.01	83.31	77.91	62.59	99.99	82.35	58.32	36.52	100.02	82.16	60.95	36.24
31	100.00	67.37	60.62	48.14	100.00	72.17	56.93	43.65	100.00	72.46	57.96	44.52
32	100.01	74.91	50.17	39.01	100.04	86.09	50.37	37.27	100.03	99.12	51.85	38.20
33	99.99	24.43	21.52	16.94	99.99	30.31	22.83	19.58	100.00	30.60	22.99	20.53
34	100.01	55.09	42.81	30.38	100.01	48.14	36.84	20.31	100.01	48.36	37.54	22.19
35	100.00	26.25	22.66	7.85	100.00	30.84	23.23	12.63	99.99	30.94	23.19	12.82
36	100.02	51.56	31.77	28.46	100.01	62.86	43.37	33.29	100.04	63.28	43.76	35.53
37	100.00	74.59	54.29	26.19	100.00	61.91	44.44	21.56	100.01	63.72	44.92	22.10
38	100.00	38.78	27.14	26.08	100.03	65.22	52.38	25.56	100.01	67.40	53.68	25.35
39	100.00	55.78	24.70	18.87	100.00	66.80	33.43	16.17	100.00	67.34	36.82	17.82
40	100.00	53.50	44.01	57.44	99.99	53.64	49.62	27.73	100.00	54.70	50.31	39.73
MEAN	100.00	66.81	49.10	36.66	100.00	60.09	44.03	30.18	100.00	60.27	44.47	30.64
STANDARD DEVIATION	0.00	40.60	25.47	17.13	0.00	15.25	12.18	11.97	0.00	15.69	12.12	11.73
Female MEAN	100.00	77.30	55.61	43.80	100.00	60.86	44.07	30.12	100.00	61.20	44.72	30.68
Female STANDARD DEVIATION	0.00	48.31	30.34	13.87	0.00	14.76	10.66	9.20	0.00	15.60	10.68	8.78
Male MEAN	99.99	56.31	42.59	29.53	99.99	59.32	43.99	30.25	99.99	59.35	44.22	30.61
Male STANDARD DEVIATION	0.00	27.25	17.09	17.12	0.00	15.68	13.53	14.21	0.00	15.73	13.39	14.07

Table 7 - Exertion Component Converted to Mean Percentage of Strength at Each Exertion Level for Leg Extention

Elbow Flexion

MEANS OF PERCENT, ALL SUBJECTS

	SLOPE				MAINTAIN STRENGTH				PEAK			
SUBJECT	100%	75%	50%	25%	100%	75%	50%	25%	100%	75%	50%	25%
1	99.99	75.50	48.38	24.80	99.99	71.91	53.87	30.35	99.99	77.96	55.71	30.50
2	100.00	54.26	86.65	46.46	100.02	53.17	54.52	30.57	99.99	64.20	65.98	43.94
3	100.00	48.43	23.09	12.43	99.99	49.84	28.61	9.22	99.99	55.72	30.58	10.43
4	99.99	37.38	58.12	25.27	99.99	65.24	49.42	29.08	99.99	71.02	56.91	39.73
5	100.00	54.44	41.48	23.92	100.00	63.75	48.45	37.16	100.00	70.85	54.05	38.07
6	100.00	72.10	39.61	27.15	100.01	44.78	28.48	14.28	100.00	54.97	31.07	21.42
7	99.99	44.14	25.58	20.14	99.99	66.50	39.31	25.47	99.99	72.12	47.06	30.90
8	100.00	66.69	52.69	33.68	100.01	65.98	50.06	33.05	100.01	69.70	49.00	34.18
9	99.99	75.88	71.31	35.66	100.00	39.41	36.09	29.62	100.00	58.31	58.09	37.21
10	100.00	59.90	64.96	22.86	100.02	73.95	46.18	22.39	100.00	61.09	46.92	20.97
11	100.00	50.93	41.65	33.53	100.00	46.09	37.22	31.95	100.00	47.45	39.04	32.24
12	100.00	22.05	23.30	10.93	99.99	19.24	14.57	9.99	100.02	19.06	16.45	11.15
13	99.99	35.78	32.49	19.78	100.00	40.56	37.12	24.10	100.00	52.85	45.88	27.45
14	100.00	35.35	31.01	16.18	100.00	52.32	49.00	25.34	99.99	77.93	61.66	28.70
15	99.99	42.42	41.04	27.10	99.99	47.00	45.37	33.41	99.99	56.76	51.65	37.58
16	100.00	83.23	83.98	39.05	99.99	55.04	49.99	23.02	100.00	64.00	62.00	31.00
17	99.99	30.54	15.11	8.87	100.00	47.18	20.81	9.60	100.00	59.91	32.40	16.83
18	100.00	51.00	28.07	27.13	100.00	37.25	20.37	11.58	100.00	39.94	21.43	13.29
19	100.00	67.97	50.73	47.18	100.01	45.35	37.45	30.33	99.99	52.07	48.88	36.19
20	100.01	55.10	37.63	28.70	100.00	57.39	34.49	26.37	99.99	61.38	34.82	26.38
21	99.99	29.76	19.03	14.11	99.99	33.90	29.68	23.46	100.00	41.80	35.99	24.44
22	100.00	63.45	56.59	53.16	99.99	38.93	37.36	27.71	100.05	45.31	43.52	32.15
23	99.99	27.27	22.11	13.23	100.01	46.85	36.31	19.96	100.00	43.80	36.01	22.82
24	100.01	47.67	40.36	27.46	100.02	53.67	30.50	14.66	100.04	53.97	39.03	19.46
25	100.00	53.63	25.17	16.48	100.01	32.42	23.96	13.44	100.00	36.50	24.62	14.93
26	100.00	53.56	28.69	27.23	100.01	44.23	31.69	21.54	100.00	55.51	41.83	28.96
27	100.00	25.32	20.96	12.58	99.99	48.73	33.04	25.20	99.99	53.86	41.86	28.77
28	99.99	52.29	50.43	38.87	99.99	66.84	66.84	42.41	99.99	68.15	70.78	45.78
29	100.00	43.93	38.34	17.95	100.00	50.40	35.79	21.04	99.99	63.81	52.07	25.38
30	100.00	43.00	40.75	22.77	99.99	54.64	39.55	28.94	100.02	65.55	47.01	32.73
31	99.99	73.68	43.09	38.39	100.00	81.26	64.68	45.85	99.99	89.51	65.12	53.32
32	100.00	108.97	57.52	51.05	100.01	59.59	41.06	27.40	99.99	77.16	54.41	37.57
33	99.99	36.43	10.12	6.81	100.00	33.59	16.57	10.56	100.00	43.80	21.40	11.80
34	100.00	44.07	54.38	33.96	100.00	56.66	46.98	29.87	100.00	58.48	49.82	30.27
35	99.99	66.66	18.67	16.43	100.00	45.42	23.27	15.62	100.00	64.79	31.12	24.84
36	99.99	35.19	27.99	21.48	100.04	42.98	29.78	27.01	100.02	44.45	34.88	28.69
37	100.00	35.71	41.72	19.99	99.99	47.22	41.83	26.44	100.00	48.82	41.64	28.56
38	99.99	43.13	39.16	25.35	100.01	62.70	49.20	31.01	99.99	66.01	53.00	29.93
39	99.99	23.31	15.79	6.16	100.01	39.76	31.97	12.04	99.99	48.68	35.50	14.99
40	100.00	48.42	35.48	21.75	100.03	48.56	30.99	22.10	100.01	62.07	37.59	23.73
MEAN	99.99	50.46	39.58	25.40	100.00	50.75	38.06	24.32	100.00	57.98	44.16	28.18
STANDARD DEVIATION	0.00	18.06	17.71	11.68	0.00	12.49	11.88	8.74	0.00	13.19	12.83	9.61
Female MEAN	99.99	53.83	46.86	30.02	100.00	52.65	40.05	24.91	100.00	58.99	45.90	29.00
Female STANDARD DEVIATION	0.00	18.58	17.28	10.75	0.00	12.19	12.29	7.64	0.00	13.42	13.90	8.84
Male MEAN	99.99	47.08	32.29	20.77	99.99	48.85	36.06	23.74	99.99	56.96	42.43	27.36
Male STANDARD DEVIATION	0.00	16.87	14.90	10.70	0.00	12.51	11.11	9.69	0.00	12.87	11.39	10.25

Table 8 - Exertion Components Converted to Mean Percentage of Strength at Each Exertion Level for Elbow Flexion

Finger Flexion

MEANS OF PERCENT, ALL SUBJECTS

	SLOPE				MAINTAIN STRENGTH				PEAK			
SUBJECT	100%	75%	50%	25%	100%	75%	50%	25%	100%	75%	50%	25%
1	100.02	82.68	50.77	33.47	100.03	67.43	75.30	43.83	100.03	77.80	84.87	44.45
2	100.04	63.58	39.35	26.73	99.99	67.33	46.66	29.99	100.09	67.93	48.75	32.15
3	100.02	61.10	211.52	23.08	100.13	66.99	38.89	14.40	100.12	69.03	42.85	17.66
4	100.01	45.37	44.22	22.27	100.06	68.67	38.76	16.98	100.12	75.26	51.74	29.56
5	100.01	106.98	67.59	52.69	100.03	73.05	65.14	63.79	100.07	90.77	73.96	70.40
6	100.00	23.84	12.87	6.23	100.15	65.69	28.03	22.43	100.11	63.42	23.62	21.13
7	100.00	61.10	50.18	19.68	99.99	72.96	46.61	26.34	99.99	74.38	56.08	32.92
8	100.02	54.38	33.64	15.16	100.44	44.02	18.34	11.59	100.18	45.95	23.84	11.53
9	100.00	55.18	23.70	37.80	100.12	64.31	40.23	40.55	100.09	76.18	52.78	37.84
10	100.06	17.91	30.46	9.13	100.15	33.71	21.32	8.91	100.14	35.08	23.70	9.74
11	100.01	46.03	45.13	23.01	100.08	55.80	40.58	26.75	100.06	51.30	38.20	22.91
12	100.02	21.28	8.21	5.66	100.22	26.23	12.40	5.07	100.16	22.98	11.55	5.79
13	100.00	67.92	59.35	45.28	100.05	56.51	44.22	42.18	100.04	74.96	55.03	49.72
14	100.00	47.79	30.42	29.38	100.07	58.74	51.67	33.74	100.06	76.16	55.16	42.54
15	100.00	45.99	39.38	27.70	100.09	42.82	33.91	25.49	100.08	50.03	36.63	26.80
16	99.99	64.99	53.56	27.13	100.11	57.11	50.36	14.73	100.10	59.07	61.26	17.50
17	100.01	35.89	27.07	13.27	100.09	44.28	19.88	7.61	100.08	53.61	31.57	13.16
18	100.06	34.73	29.15	21.59	100.18	36.19	25.98	12.00	100.08	40.66	27.36	13.97
19	100.11	51.87	79.93	43.94	100.03	70.45	69.54	49.33	100.09	65.26	70.34	47.00
20	100.14	50.46	35.08	25.62	100.09	47.80	30.37	25.73	100.18	48.68	31.83	31.68
21	100.03	46.94	40.54	20.92	100.08	61.48	52.23	23.84	100.02	60.13	51.34	25.42
22	100.02	78.39	58.29	54.12	100.50	44.66	48.85	32.60	100.10	57.50	40.65	31.85
23	100.05	27.28	7.28	7.55	100.11	35.87	20.19	13.71	100.08	36.74	19.48	13.43
24	100.05	31.52	44.15	8.07	99.99	45.44	28.53	7.63	100.21	49.99	40.83	10.13
25	100.00	50.61	44.32	16.56	100.11	44.12	31.85	13.88	100.07	47.07	37.02	17.04
26	100.00	16.98	14.73	4.29	100.10	33.05	21.78	7.43	100.11	31.07	24.95	8.77
27	100.03	49.15	38.29	23.62	100.03	41.51	34.88	16.33	100.03	44.86	35.76	16.36
28	100.03	61.03	45.20	20.71	100.14	58.53	34.97	17.51	100.05	58.50	38.03	18.82
29	100.00	77.16	40.86	28.45	100.08	47.68	30.84	18.48	100.07	56.37	34.75	18.99
30	100.08	59.91	46.75	24.45	100.06	67.95	42.23	28.72	100.21	66.68	41.40	24.88
31	100.01	76.30	52.77	26.63	100.07	79.15	50.93	27.69	100.12	74.66	52.83	28.58
32	100.03	52.47	36.24	11.11	100.18	53.23	43.69	21.31	100.04	53.66	42.45	19.63
33	100.00	19.02	12.03	4.62	100.07	37.21	21.45	6.02	100.04	34.79	23.00	7.32
34	100.03	33.22	64.52	18.66	100.07	39.95	28.85	10.91	100.14	42.65	36.19	11.64
35	100.00	56.92	34.61	9.00	100.04	35.22	24.03	3.74	100.01	45.36	32.30	5.08
36	100.07	36.96	21.10	15.37	100.27	42.59	36.26	18.72	100.08	38.33	25.90	15.56
37	100.06	42.09	28.44	32.58	100.31	45.74	37.49	14.53	100.29	48.71	38.91	19.90
38	100.02	19.20	16.62	14.21	100.20	28.96	18.34	11.57	100.17	31.10	20.55	16.94
39	100.04	13.21	13.56	4.98	100.13	19.31	14.30	8.10	100.10	19.04	14.91	7.25
40	100.03	21.21	18.67	11.19	100.18	33.32	26.43	6.93	100.03	33.19	27.93	9.99
MEAN	100.02	46.71	41.26	21.64	100.12	50.37	36.15	20.77	100.09	53.72	39.50	22.64
STANDARD DEVIATION	0.00	19.99	32.02	12.62	0.08	14.80	14.53	13.28	0.03	16.68	16.02	13.84
Female MEAN	100.03	41.76	34.16	18.55	100.15	47.65	32.69	17.22	100.11	49.89	34.88	19.18
Female STANDARD DEVIATION	0.00	18.11	15.27	11.19	0.10	13.40	11.42	8.86	0.00	15.12	12.61	9.69
Male MEAN	100.01	51.66	48.36	24.74	100.08	53.09	39.62	24.32	100.07	57.55	44.12	26.11
Male STANDARD DEVIATION	0.00	20.55	41.42	13.21	0.04	15.61	16.36	15.78	0.04	17.29	17.65	16.29

Table 9 - Exertion Components Converted to Mean Percentage of Strength at Each Exertion Level for Finger Flexion

Leg Flexion

MEANS OF PERCENT DIFFERENCE, ALL SUBJECTS

SUBJECT	SLOPE 100%	SLOPE 75%	SLOPE 50%	SLOPE 25%	MAINTAIN STRENGTH 100%	MAINTAIN STRENGTH 75%	MAINTAIN STRENGTH 50%	MAINTAIN STRENGTH 25%	PEAK 100%	PEAK 75%	PEAK 50%	PEAK 25%
1	40.43	13.16	10.13	4.69	5.26	10.52	16.19	3.64	5.17	10.75	15.53	3.98
2	13.77	10.23	14.11	8.18	4.18	16.50	6.43	3.06	4.72	17.52	8.46	3.93
3	67.75	4.34	2.94	1.61	11.53	8.23	6.04	2.19	13.82	8.50	5.31	1.59
4	39.31	30.21	9.37	31.49	3.99	11.32	5.33	13.33	3.79	10.12	5.06	12.65
5	26.49	72.78	12.78	9.79	11.79	8.30	11.02	11.28	13.03	9.12	10.46	10.75
6	33.40	25.33	12.41	3.23	14.20	17.28	22.84	7.82	16.44	18.39	23.96	8.00
7	42.37	5.40	2.34	4.44	7.31	4.06	3.25	5.28	6.34	3.96	3.71	5.15
8	37.77	29.21	7.00	8.26	9.98	14.86	7.10	5.94	8.21	13.72	6.96	6.86
9	74.83	11.58	7.47	4.17	11.46	7.11	5.53	7.51	12.74	8.49	5.48	9.26
10	19.89	9.20	14.09	1.23	13.51	13.96	6.35	0.68	13.03	13.64	5.94	1.18
11	21.72	12.62	7.86	9.53	9.77	7.82	7.47	6.04	8.20	6.58	6.92	6.58
12	15.72	4.33	4.14	7.89	14.28	3.57	5.42	5.71	13.96	3.41	5.12	4.98
13	42.93	17.26	1.87	7.22	3.44	21.46	5.27	2.44	2.77	21.46	5.40	2.55
14	76.94	7.41	14.27	0.49	3.95	8.82	6.95	1.71	3.62	10.29	7.06	1.71
15	65.87	41.25	43.81	12.54	27.72	27.22	17.81	12.61	22.57	24.88	16.12	11.28
16	58.05	31.39	18.03	13.23	16.66	9.57	5.83	2.50	16.66	8.74	6.25	1.25
17	35.92	8.81	4.78	8.41	3.61	5.42	7.73	4.56	3.36	5.03	8.52	4.49
18	25.00	8.09	16.36	6.25	4.25	6.91	3.19	5.31	3.70	6.94	4.52	5.45
19	14.77	4.43	15.84	7.43	7.19	7.79	8.45	9.32	6.90	7.43	9.26	9.37
20	13.27	18.05	17.00	19.88	7.55	10.22	11.55	12.44	6.12	9.28	9.28	11.81
21	30.39	11.63	0.34	8.33	2.73	3.02	6.62	6.91	2.69	3.37	6.87	7.78
22	15.16	4.11	15.23	3.09	6.35	11.72	13.47	7.23	5.80	10.37	14.32	7.90
23	18.97	14.61	6.08	12.60	9.23	7.76	5.35	5.92	9.29	7.68	5.11	7.81
24	25.23	47.32	12.89	51.23	6.38	11.70	11.70	3.85	6.54	12.71	11.67	4.41
25	45.22	12.95	7.35	6.56	22.61	9.69	11.39	7.63	21.87	9.81	11.11	7.68
26	10.98	16.95	11.44	11.01	3.03	10.92	15.68	9.91	3.25	10.45	15.86	9.87
27	38.02	5.73	6.05	4.43	4.76	9.51	4.21	2.38	2.06	9.20	4.18	2.25
28	9.96	13.43	7.28	17.72	3.95	11.17	5.91	10.52	3.54	11.28	5.16	9.93
29	19.92	29.31	8.71	11.09	8.95	5.69	5.50	4.10	15.89	5.45	2.93	3.70
30	22.44	5.67	12.80	9.34	8.55	3.34	3.16	8.91	9.19	3.32	3.10	8.38
31	15.73	27.53	10.65	4.64	4.49	6.39	6.68	7.03	4.69	6.32	6.56	7.13
32	15.22	15.57	6.96	8.58	9.50	3.92	4.35	8.20	9.24	3.95	3.95	7.76
33	47.36	24.15	2.63	10.53	8.95	7.93	2.89	3.06	9.97	7.63	2.75	2.39
34	6.13	11.13	13.02	12.98	6.13	18.66	6.04	5.95	4.02	15.59	6.00	5.14
35	45.99	9.57	9.07	4.38	7.32	5.44	3.52	4.11	7.49	5.66	3.66	4.50
36	24.79	23.89	21.50	18.01	6.66	9.94	8.70	4.53	7.45	9.70	7.45	4.07
37	15.36	2.95	8.37	5.30	13.76	3.00	6.80	8.20	14.45	2.64	7.03	8.20
38	65.32	10.03	2.70	2.55	11.04	4.47	5.37	6.26	11.30	4.00	5.72	5.43
39	34.07	13.54	8.42	3.74	11.86	8.06	12.00	3.79	12.27	10.86	11.73	3.28
40	33.19	20.20	23.56	8.01	2.16	8.37	9.21	4.43	1.90	10.35	7.78	4.32
MEAN	32.64	17.13	10.79	9.60	8.75	9.54	7.95	6.15	8.70	9.46	7.80	6.11
STANDARD DEVIATION	18.63	13.64	7.52	8.81	5.28	5.12	4.35	3.11	5.29	4.89	4.35	3.05
Female MEAN	28.07	17.08	12.70	12.13	7.81	10.36	8.22	6.41	7.62	10.18	8.18	6.24
STANDARD DEVIATION	18.82	10.97	5.24	11.53	4.15	4.38	4.67	3.33	4.41	4.27	4.83	3.19
Male MEAN	37.20	17.17	8.87	7.07	9.68	8.72	7.68	5.89	9.77	8.74	7.43	5.98
STANDARD DEVIATION	17.27	15.87	8.84	3.08	6.07	5.65	3.98	2.85	5.85	5.33	3.78	2.90

Table 10 - Percent Deviation from Exertion Level Mean for Leg Flexion

Leg Extension

MEANS OF PERCENT DIFFERENCE, ALL SUBJECTS

SUBJECT	SLOPE 100%	SLOPE 75%	SLOPE 50%	SLOPE 25%	MAINTAIN STRENGTH 100%	MAINTAIN STRENGTH 75%	MAINTAIN STRENGTH 50%	MAINTAIN STRENGTH 25%	PEAK 100%	PEAK 75%	PEAK 50%	PEAK 25%
1	29.93	15.55	21.17	9.71	12.06	8.17	8.94	7.97	11.36	9.84	9.08	8.71
2	16.15	16.25	32.51	14.04	8.19	5.58	13.07	8.62	8.08	9.69	12.69	8.09
3	101.53	9.38	19.57	5.28	10.14	12.09	9.25	3.90	4.63	8.27	8.60	4.30
4	8.52	194.96	31.13	31.61	5.26	5.26	6.57	7.01	7.02	5.37	5.78	6.60
5	16.66	15.37	6.36	7.97	7.56	2.93	8.82	6.89	6.95	3.88	8.57	6.73
6	36.63	39.28	188.85	10.89	6.86	8.27	11.64	6.62	8.30	9.02	11.31	6.23
7	23.07	25.64	20.45	20.49	11.56	2.38	7.48	6.12	8.97	1.92	6.56	4.81
8	18.73	17.92	6.71	5.75	10.14	16.66	4.05	5.43	11.41	17.32	4.01	6.72
9	21.28	20.04	4.23	7.92	9.00	6.87	8.05	12.08	7.65	6.81	8.58	12.29
10	23.88	21.06	9.46	4.95	15.56	7.28	4.63	3.64	5.16	7.96	4.77	3.82
11	8.75	12.85	14.88	4.56	6.05	6.47	3.14	4.22	6.52	6.52	3.64	4.32
12	11.39	7.64	6.14	2.93	24.60	4.61	5.32	1.77	25.08	4.82	5.51	1.92
13	11.76	22.05	12.71	2.94	13.11	4.46	2.72	1.68	11.37	4.97	3.38	1.79
14	17.24	8.66	7.71	17.82	6.25	7.70	10.52	5.52	5.84	8.27	10.55	6.93
15	74.54	26.90	28.88	9.23	9.54	14.56	10.35	10.35	9.93	14.51	10.09	10.72
16	28.46	37.36	22.30	16.77	4.28	5.71	4.28	5.00	4.28	2.85	2.14	4.28
17	52.30	16.72	2.02	3.21	3.22	7.05	4.83	3.97	3.12	7.32	4.21	3.77
18	14.29	66.66	6.52	5.18	3.03	11.10	5.25	2.01	6.67	9.73	5.12	3.20
19	19.97	8.54	8.11	16.68	15.41	9.68	6.14	9.55	22.47	9.81	6.05	9.56
20	15.90	10.83	8.97	59.48	10.15	6.14	9.35	2.00	8.52	4.91	9.56	2.07
21	15.22	37.17	22.67	6.90	11.08	12.95	13.37	6.32	9.90	12.97	13.99	6.48
22	10.83	2.91	18.37	3.40	6.49	2.93	5.22	5.22	6.56	2.87	6.00	8.88
23	18.03	4.17	8.45	1.86	1.93	7.74	6.16	1.13	1.61	7.16	7.19	3.11
24	31.97	11.72	10.99	10.01	10.07	10.35	8.67	3.32	8.65	10.86	8.57	4.85
25	40.57	7.60	3.50	3.58	13.10	3.07	4.61	6.08	13.54	3.66	4.77	6.67
26	19.99	14.08	6.34	4.20	4.00	7.82	6.29	5.07	3.75	7.87	7.06	5.45
27	7.35	8.18	3.64	2.47	6.75	9.60	4.20	1.50	7.94	8.87	4.65	2.19
28	9.46	2.58	10.80	3.36	17.62	10.13	5.06	7.72	17.28	10.04	5.13	7.47
29	12.16	13.40	13.44	9.17	7.89	7.23	1.80	5.24	7.50	7.40	5.34	6.00
30	17.86	15.48	8.54	15.97	8.05	2.98	5.00	5.06	8.25	3.49	4.96	5.76
31	18.17	24.87	14.70	8.20	1.56	4.69	9.07	1.65	1.81	4.90	8.70	1.88
32	10.23	7.11	6.48	15.49	19.71	9.61	5.23	10.82	18.80	19.73	5.73	10.89
33	15.70	13.03	13.50	7.72	1.60	5.68	5.79	7.15	1.83	5.20	5.94	7.49
34	36.10	2.61	7.28	2.01	7.68	7.15	6.81	2.87	7.59	6.34	6.73	4.07
35	30.00	13.75	10.66	2.73	11.65	5.09	2.77	3.00	6.19	5.41	2.64	3.28
36	20.99	17.08	2.88	5.79	18.23	11.60	5.09	3.50	17.11	12.44	4.71	3.72
37	13.63	11.26	13.32	5.98	5.73	8.08	11.28	2.04	5.78	8.15	11.70	1.94
38	40.56	18.57	7.34	20.91	19.60	6.64	4.89	3.77	18.33	5.81	3.89	3.90
39	25.31	14.47	15.89	4.75	18.20	9.73	11.94	3.88	15.57	9.20	13.54	4.97
40	29.95	11.46	13.26	26.31	5.46	9.85	7.29	7.29	5.04	11.49	7.59	10.66
MEAN	24.37	21.12	16.76	10.45	9.70	7.74	6.87	5.18	9.15	7.94	6.97	5.55
STANDARD DEVIATION	17.98	30.24	28.56	10.47	5.47	3.20	2.91	2.70	5.46	3.77	2.94	2.69
Female MEAN	20.95	26.21	20.62	13.84	10.56	8.06	6.71	5.13	10.08	8.54	6.58	5.55
Female STANDARD DEVIATION	9.60	41.44	39.40	13.25	6.16	3.14	2.52	2.30	5.77	4.34	2.64	2.39
Male MEAN	27.79	16.04	12.90	7.06	8.85	7.42	7.03	5.23	8.23	7.33	7.36	5.54
Male STANDARD DEVIATION	23.05	7.80	7.05	4.57	4.52	3.24	3.25	3.04	4.95	2.98	3.17	2.96

Table 11 - Percent Deviation from Exertion Level Mean for Leg Extension

Elbow Flexion

MEANS OF PERCENT DIFFERENCE, ALL SUBJECTS

	SLOPE				MAINTAIN STRENGTH				PEAK			
SUBJECT	100%	75%	50%	25%	100%	75%	50%	25%	100%	75%	50%	25%
1	21.65	24.99	16.13	8.52	3.19	13.47	6.39	5.70	2.96	13.56	6.56	5.92
2	26.11	9.03	7.10	18.69	7.22	6.17	4.36	5.57	3.81	5.92	4.53	9.34
3	14.27	10.34	7.22	6.65	8.91	7.38	6.46	2.15	8.82	8.38	5.87	3.08
4	16.65	11.47	37.59	2.87	3.67	18.92	11.01	5.36	2.82	16.66	14.61	7.94
5	12.40	34.08	13.08	9.23	12.88	10.20	8.39	10.80	7.63	15.36	9.73	10.33
6	15.69	33.37	14.70	10.66	11.13	6.79	8.32	6.39	5.56	12.54	7.82	6.20
7	13.64	10.38	10.78	4.38	4.85	5.09	5.33	6.06	5.85	3.74	7.72	7.96
8	22.76	11.90	17.31	11.84	3.03	11.54	13.61	3.64	13.58	5.88	17.09	3.04
9	39.06	35.36	26.02	15.98	20.07	5.82	7.87	5.11	8.87	10.08	12.13	9.06
10	5.15	16.13	16.60	4.86	30.46	15.80	5.45	6.10	10.02	11.70	7.17	6.38
11	4.88	14.56	10.92	7.36	5.71	2.86	6.53	3.50	8.36	5.27	8.48	3.66
12	19.28	7.11	9.10	3.49	6.72	2.24	5.04	4.01	5.69	3.24	4.90	3.08
13	19.53	6.23	2.61	7.53	3.77	5.67	4.82	7.78	3.58	10.14	5.77	7.69
14	30.20	9.49	6.74	2.90	4.04	5.52	8.24	6.78	1.67	6.86	1.57	5.83
15	13.64	12.11	14.78	6.74	1.09	7.46	7.33	6.25	0.38	9.96	6.39	5.50
16	19.94	13.17	17.97	10.49	12.91	10.11	12.92	7.02	12.00	16.00	16.00	9.00
17	33.32	2.77	4.35	2.02	4.51	2.57	7.44	2.36	3.06	6.73	12.07	3.27
18	23.84	25.24	10.95	2.87	3.74	7.34	2.79	0.44	2.49	7.36	2.05	1.10
19	6.91	13.09	7.01	31.84	15.63	12.45	13.02	12.52	8.95	13.58	9.09	15.44
20	22.67	4.46	20.36	5.05	6.52	5.21	8.98	1.44	5.55	5.27	8.50	1.94
21	20.31	11.91	3.61	4.65	4.66	7.33	2.02	7.36	3.26	9.08	4.88	6.45
22	13.26	13.38	10.22	3.03	16.66	7.54	3.33	0.88	14.28	9.01	7.14	0.81
23	18.64	6.61	2.11	2.38	5.22	6.07	2.86	0.63	1.13	4.62	1.32	2.65
24	6.29	10.93	12.28	6.48	20.92	4.25	6.62	3.34	12.67	4.86	7.80	2.49
25	5.68	17.26	9.86	6.44	14.25	7.04	3.32	4.35	15.07	3.24	3.37	5.15
26	5.87	6.93	9.11	12.84	4.01	7.71	3.48	6.90	3.17	7.38	4.78	12.46
27	37.05	3.17	10.49	0.70	1.40	1.68	7.56	2.52	2.02	4.92	13.68	2.11
28	20.01	13.66	10.23	16.13	2.25	7.01	6.17	9.26	3.15	8.15	3.28	9.47
29	12.50	13.20	4.60	2.89	6.14	3.30	2.31	4.26	6.31	7.03	4.30	3.48
30	39.72	10.53	7.66	4.63	16.84	5.52	2.14	2.98	16.25	11.12	5.99	1.77
31	40.65	3.86	9.78	4.05	4.18	4.14	13.72	5.00	1.27	4.68	9.70	4.83
32	21.03	29.10	5.83	8.80	20.11	5.47	5.14	6.64	20.83	7.16	4.12	8.57
33	31.17	12.14	3.57	2.16	3.84	6.71	4.18	3.78	4.81	12.94	5.23	3.16
34	32.53	9.76	15.68	14.88	22.20	7.34	7.93	3.68	20.88	9.84	12.24	4.38
35	16.67	16.66	3.09	3.67	0.61	1.34	5.29	2.02	1.17	2.61	5.40	3.98
36	33.33	5.20	20.78	12.11	12.56	10.68	5.34	4.89	8.11	8.92	12.43	2.64
37	26.66	5.64	21.03	3.23	2.63	7.83	16.57	7.43	5.96	9.22	15.45	6.92
38	20.58	8.62	13.17	7.64	23.76	7.88	1.13	5.86	20.12	11.08	3.61	3.88
39	18.64	9.72	4.81	1.14	3.79	10.70	5.01	1.38	3.96	12.41	4.56	1.23
40	21.52	9.33	9.35	10.54	7.02	4.95	9.92	4.75	11.49	7.13	10.70	7.21
MEAN	20.59	13.07	11.46	7.55	9.07	7.17	6.70	4.92	7.43	8.58	7.70	5.48
STANDARD DEVIATION	9.80	8.21	7.02	5.91	7.32	3.64	3.55	2.63	5.59	3.61	4.06	3.25
Female MEAN	20.82	12.93	13.63	8.53	11.78	7.89	6.59	4.79	9.70	8.80	7.81	5.37
STANDARD DEVIATION	8.85	7.49	7.05	4.76	8.12	3.83	3.39	2.20	6.28	3.44	4.50	3.25
Male MEAN	20.36	13.20	9.29	6.57	6.36	6.45	6.82	5.04	5.16	8.37	7.58	5.59
STANDARD DEVIATION	10.66	8.87	6.29	6.74	5.14	3.29	3.71	2.99	3.57	3.77	3.57	3.26

Table 12 - Percent Deviation from Exertion Level Mean for Elbow Flexion

Finger Flexion

Means of Percent Difference, All Subjects

	SLOPE				MAINTAIN STRENGTH				PEAK			
SUBJECT	100%	75%	50%	25%	100%	75%	50%	25%	100%	75%	50%	25%
1	23.58	14.61	14.28	18.23	9.55	8.99	12.36	16.85	5.56	9.09	10.10	16.16
2	19.88	20.15	19.31	8.78	16.00	17.66	18.66	11.73	15.04	17.37	17.11	11.41
3	37.49	22.97	269.15	11.84	4.32	10.80	5.04	3.60	6.54	8.17	4.90	6.21
4	36.61	6.63	13.92	9.33	15.13	13.66	5.53	7.38	14.11	10.75	12.76	12.09
5	17.65	6.14	20.50	9.75	1.46	7.33	3.27	12.70	1.57	4.54	6.32	15.82
6	12.39	15.03	5.58	0.92	12.01	11.21	13.61	9.61	9.32	9.33	11.19	8.70
7	18.64	6.64	24.36	5.81	12.16	4.05	2.02	3.37	12.19	4.26	2.44	10.97
8	29.50	19.97	11.19	5.94	14.41	11.31	2.30	4.67	6.48	7.30	3.46	3.84
9	15.67	23.61	10.02	3.76	14.57	4.11	8.07	3.79	8.96	5.97	7.46	2.98
10	24.00	10.30	27.01	5.39	12.11	19.99	14.21	2.04	12.89	20.67	15.74	2.21
11	20.74	10.04	9.46	2.67	15.22	4.14	7.37	5.07	12.19	6.00	7.64	3.81
12	17.19	4.45	2.81	1.52	16.78	6.26	2.48	1.88	1.19	5.41	2.85	0.76
13	12.66	8.28	5.18	14.51	11.76	10.00	4.82	5.56	9.60	10.64	6.71	7.59
14	25.67	7.70	1.60	13.87	9.29	15.00	5.17	3.04	2.61	6.44	10.26	5.09
15	27.33	26.67	18.76	4.36	3.85	14.43	10.34	4.81	2.67	18.76	11.16	4.46
16	10.71	15.35	20.71	11.77	15.04	10.44	17.19	4.91	11.21	12.03	19.69	6.56
17	15.70	10.58	8.15	4.79	5.70	11.61	2.77	3.63	10.53	16.26	6.16	5.66
18	7.73	10.57	8.50	7.31	8.50	3.49	2.26	2.17	4.87	3.39	2.28	2.45
19	24.42	25.90	22.61	12.96	22.99	16.66	7.17	15.09	16.21	16.75	12.69	13.01
20	28.77	11.03	17.74	9.85	24.15	10.95	5.47	16.00	23.87	11.23	3.74	23.50
21	30.45	19.98	2.36	8.40	2.80	6.37	5.01	4.86	3.01	7.61	3.84	4.97
22	43.32	60.87	58.38	22.05	36.54	20.30	32.35	17.18	38.94	38.62	36.52	13.02
23	7.68	6.54	1.57	3.38	12.44	15.04	5.38	5.61	16.92	15.47	4.20	5.36
24	25.98	5.84	31.92	5.54	18.18	5.45	9.35	1.09	15.38	10.20	21.61	2.36
25	47.11	3.49	16.49	5.28	42.81	13.41	5.83	3.77	33.54	9.38	4.52	5.09
26	38.05	5.32	8.27	2.42	18.30	6.75	4.03	5.37	4.26	5.82	7.98	5.57
27	30.67	9.52	6.57	5.33	5.96	10.59	7.50	3.75	3.03	12.93	5.45	3.12
28	29.20	23.73	17.32	13.18	10.31	14.54	4.04	7.50	1.59	15.82	8.63	6.35
29	19.37	14.96	7.29	11.85	5.24	9.43	5.52	1.98	5.49	5.85	5.49	0.64
30	20.47	26.28	19.25	4.38	6.67	11.49	11.49	6.89	11.27	14.64	11.77	4.96
31	3.68	11.30	13.87	8.62	6.53	12.17	11.14	11.19	10.16	11.37	10.12	8.11
32	56.08	11.18	12.18	3.09	6.67	4.86	16.01	1.37	2.62	4.36	13.68	1.58
33	51.08	7.95	4.10	2.07	14.85	2.95	3.22	2.26	16.41	4.74	3.66	2.24
34	23.49	8.58	8.92	5.23	8.43	2.89	7.04	0.92	6.95	1.73	7.39	0.52
35	11.53	24.61	5.76	3.29	5.35	5.21	3.12	1.39	1.82	4.89	6.08	2.46
36	30.96	3.34	11.43	8.43	25.91	7.64	13.73	4.78	10.97	6.73	8.33	4.37
37	67.44	13.39	6.78	15.04	36.76	3.59	7.26	4.48	36.82	4.00	7.03	8.00
38	41.85	4.00	3.03	11.78	20.81	3.21	6.32	3.21	25.00	5.92	4.72	6.71
39	28.91	9.48	7.97	2.06	16.52	6.75	3.51	2.20	11.91	8.29	4.71	1.98
40	25.08	12.36	5.83	9.57	11.55	15.79	6.09	4.23	9.77	15.30	5.89	7.10
MEAN	26.46	13.98	19.50	7.85	13.94	9.76	7.95	5.78	11.33	10.20	8.90	6.44
STANDARD DEVIATION	13.49	10.22	41.28	4.84	9.15	4.84	5.83	4.46	9.16	6.56	6.37	4.82
Female MEAN	27.34	14.13	15.24	8.01	15.33	10.64	9.86	5.77	11.41	11.15	11.27	6.45
STANDARD DEVIATION	11.49	12.51	12.64	4.90	7.18	5.34	7.27	4.54	9.04	8.00	7.94	5.26
Male MEAN	25.58	13.83	23.76	7.69	12.54	8.88	6.03	5.79	11.25	9.24	6.53	6.43
STANDARD DEVIATION	15.18	7.24	56.67	4.77	10.59	4.08	2.80	4.33	9.28	4.50	2.62	4.35

Table 13 - Percent Deviation from Exertion Level Mean for Finger Flexion

(B) Variability Analysis

Each subject's percent difference from his/her exertion level average for each exertion was used as input into the variability analysis to test the hypothesis that increased variability in repeated trials occurs with lowered exertion levels. This analysis was performed for all subjects collectively and for male subjects and female subjects separately, for each type of exertion.

As described in the "Statistical Treatment" section, these measures of performance were calculated in several ways, based either on the average of the 100% level exertions, or based on the maximal peak force exerted by each subject. For each of these types of computational treatments the subject's percent difference from the exertion level average was calculated. Thus, the data were normalized in four different ways and each situation described was tested for the significance of variability difference via one-way analysis of variance (ANOVA) techniques.

Percentages Based Upon 100% Level Average

The ANAOVAs analyzing the maintained portion of the strength exertion (for the total group data, female data and male data) are presented for LF, LE, EF and FF in Tables 14 through 17. The group ANOVAs indicated significant differences in variability for each type of exertion ($F_{LF} = 3.95$, $F_{LE} = 9.86$, $F_{EF} = 5.26$, $F_{FF} = 11.58$, d.f. = 3/156, $p \leq .01$). However the order of variability did not agree with the hypothesis. The LE, EF and FF types of exertions indicated a trend suggesting increasing variability with increased exertion levels. Significant F-ratios were found for the female subject group for the LE, EF and FF types of exertion (F_{LE} = 6.74, F_{EF} = 6.88, F_{FF} = 7.60, d.f. = 3/76, $p \leq .01$). This same trend was evident for the female variability analysis. The only significant ANOVA for the group of male subjects was found for the FF type of exertion (F_{FF} = 4.83, d.f. = 3/76, $p \leq .01$). Again, the same trend was noted.

Similarly, one-way ANOVA's analyzing the peak portion of the strength exertion were calculated. This was done for the group considered collectively and for each sex independently. These results for LF, LE, EF and FF are presented in Tables 18 through 21 respectively. Fewer significant results were evident. In the group analysis only the LF and LE types of exertion exhibited significant F-ratio statistics (F_{LF} = 4.02, F_{LE} = 6.05, d.f. = 3/156, $p \leq .01$). In this case only the LE exertion data indicated a trend of increasing variability when attempting to reach higher exertion levels. The analysis by sex indicated a significant F-ratio only for the LE type of exertion for female subjects (F_{LE} = 4.78, d.f. = 3/76, $p \leq .01$). In this case the same trend with regard to a variability pattern was noted.

UNIVARIATE 1-WAY ANOVA CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 5.LEGFL N= 160 OUT OF 160

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	4029.1	1343.0	3.9496	.0095
WITHIN	156	53048.	340.05		
TOTAL	159	57077.	(RANDOM EFFECTS STATISTICS)		

ETA= .2657 ETA-SQR= .0706 (VAR COMP= 25.075 %VAR AMONG= 6.87)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	40	35.030	459.07	21.426
75%	40	38.189	430.76	20.755
50%	40	31.852	310.72	17.627
25%	40	24.654	159.64	12.635
GRAND	160	32.431	358.97	18.947

UNIVARIATE 1-WAY ANOVA CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 5.LEGFL N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	2562.5	854.17	2.9201	.0394
WITHIN	76	22231.	292.51		
TOTAL	79	24794.	(RANDOM EFFECTS STATISTICS)		

ETA= .3215 ETA-SQR= .1034 (VAR COMP= 28.083 %VAR AMONG= 8.76)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	31.284	290.93	17.057
75%	20	41.468	323.27	17.980
50%	20	32.938	367.94	19.182
25%	20	25.681	187.91	13.708
GRAND	80	32.843	313.84	17.716

UNIVARIATE 1-WAY ANOVA CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 5.LEGFL N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	2520.2	840.08	2.1471	.1012
WITHIN	76	29736.	391.26		
TOTAL	79	32256.	(RANDOM EFFECTS STATISTICS)		

ETA= .2795 ETA-SQR= .0781 (VAR COMP= 22.461 %VAR AMONG= 5.42)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	38.776	621.83	24.936
75%	20	34.910	538.29	23.201
50%	20	30.766	267.37	16.351
25%	20	23.627	137.55	11.728
GRAND	80	32.020	408.30	20.207

Table 14 - Maintained Level Exertion Component (based upon 100% exertion level average) ANOVA for Leg Flexion

<ANOVA VAR=4,5,6,7 CASES=1-160 STRAT=V3>

UNIVARIATE 1-WAY ANOVA CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 4.LEGEX N= 160 OUT OF 160

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	6802.5	2267.5	9.8578	.0000
WITHIN	156	35884.	230.02		
TOTAL	159	42686.	(RANDOM EFFECTS STATISTICS)		

ETA= .3992 ETA-SQR= .1594 (VAR COMP= 50.937 %VAR AMONG= 18.13)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	40	38.862	491.29	22.165
75%	40	31.013	169.16	13.006
50%	40	27.518	139.73	11.821
25%	40	20.770	119.91	10.950
GRAND	160	29.541	268.47	16.385

<ANOVA VAR=4,5,6,7 CASES=V2:1 STRAT=V3>

UNIVARIATE 1-WAY ANOVA CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 4.LEGEX N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	5070.1	1690.0	6.7370	.0004
WITHIN	76	19065.	250.86		
TOTAL	79	24135.	(RANDOM EFFECTS STATISTICS)		

ETA= .4583 ETA-SQR= .2101 (VAR COMP= 71.959 %VAR AMONG= 22.29)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	42.272	639.42	25.287
75%	20	32.300	166.72	12.912
50%	20	26.870	107.81	10.383
25%	20	20.575	89.479	9.4593
GRAND	80	30.504	305.51	17.479

<ANOVA VAR=4,5,6,7 CASES=V2:2 STRAT=V3>

UNIVARIATE 1-WAY ANOVA CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 4.LEGEX N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	2133.7	711.23	3.3226	.0241
WITHIN	76	16269.	214.06		
TOTAL	79	18402.	(RANDOM EFFECTS STATISTICS)		

ETA= .3405 ETA-SQR= .1159 (VAR COMP= 24.859 %VAR AMONG= 10.40)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	35.451	344.52	18.561
75%	20	29.727	177.02	13.305
50%	20	28.166	178.13	13.347
25%	20	20.965	156.57	12.513
GRAND	80	28.577	232.96	15.262

Table 15 - Maintained Level Exertion Component (based upon 100% exertion level average) ANOVA for Leg Extention

UNIVARIATE 1-WAY ANOVA CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 6.ELBOW N= 160 OUT OF 160

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	5598.9	1866.3	5.2580	.0018
WITHIN	156	55371.	354.95		
TOTAL	159	60970.	(RANDOM EFFECTS STATISTICS)		

ETA= .3030 ETA-SQR= .0919 (VAR COMP= 37.784 %VAR AMONG= 9.62)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	40	36.334	879.67	29.659
75%	40	28.735	218.44	14.780
50%	40	26.859	207.96	14.421
25%	40	19.712	113.72	10.664
GRAND	160	27.910	383.46	19.582

UNIVARIATE 1-WAY ANOVA CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 6.ELBOW N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	8443.9	2814.6	6.8843	.0004
WITHIN	76	31072.	408.84		
TOTAL	79	39516.	(RANDOM EFFECTS STATISTICS)		

ETA= .4623 ETA-SQR= .2137 (VAR COMP= 120.29 %VAR AMONG= 22.73)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	47.178	1112.2	33.349
75%	20	31.622	247.73	15.740
50%	20	26.405	193.66	13.916
25%	20	19.210	81.801	9.0444
GRAND	80	31.104	500.20	22.365

UNIVARIATE 1-WAY ANOVA CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 6.ELBOW N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	577.82	192.61	.76065	.5196
WITHIN	76	19244.	253.21		
TOTAL	79	19822.	(RANDOM EFFECTS STATISTICS)		

ETA= .1707 ETA-SQR= .0292 (VAR COMP= -3.0303 %VAR AMONG= -0.1

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	25.490	445.88	21.116
75%	20	25.848	183.10	13.531
50%	20	27.310	232.77	15.257
25%	20	20.213	151.09	12.292
GRAND	80	24.716	250.91	15.840

Table 16 - Maintained Level Exertion Component (based upon 100% exertion level average) ANOVA for Elbow Flexion

UNIVARIATE 1-WAY ANOVA CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 7.FINGER N= 160 OUT OF 160

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	22967.	7655.7	11.579	.0000
WITHIN	156	.10314 +6	661.15		
TOTAL	159	.12611 +6	(RANDOM EFFECTS STATISTICS)		

ETA= .4268 ETA-SQR= .1821 (VAR COMP= 174.86 %VAR AMONG= 20.92)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	40	55.786	1377.1	37.109
75%	40	39.076	384.55	19.610
50%	40	31.833	558.64	23.636
25%	40	23.175	324.33	18.009
GRAND	160	37.467	793.12	28.162

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UNIVARIATE 1-WAY ANOVA CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 7.FINGER N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	14752.	4917.4	7.5963	.0002
WITHIN	76	49197.	647.33		
TOTAL	79	63949.	(RANDOM EFFECTS STATISTICS)		

ETA= .4803 ETA-SQR= .2307 (VAR COMP= 213.50 %VAR AMONG= 24.80)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	61.382	868.84	29.476
75%	20	42.598	481.26	21.938
50%	20	39.496	890.81	29.846
25%	20	23.137	348.42	18.666
GRAND	80	41.653	809.49	28.451

UNIVARIATE 1-WAY ANOVA CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 7.FINGER N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	9509.3	3169.8	4.8331	.0039
WITHIN	76	49845.	655.85		
TOTAL	79	59354.	(RANDOM EFFECTS STATISTICS)		

ETA= .4003 ETA-SQR= .1602 (VAR COMP= 125.70 %VAR AMONG= 16.08)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	50.190	1891.9	43.496
75%	20	35.553	281.95	16.791
50%	20	24.170	132.25	11.500
25%	20	23.212	317.32	17.813
GRAND	80	33.281	751.31	27.410

Table 17 - Maintained Level Exertion Component (based upon 100% exertion level average) ANOVA for Finger Flexion

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UNIVARIATE 1-WAY ANOVA  CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 5.LEGFL   N= 160 OUT OF 160

SOURCE                DF  SUM OF SORS   MEAN SOR   F-STATISTIC  SIGNIF

BETWEEN                3     3976.3      1325.4      4.0196      .0087
WITHIN               156     51440.      329.74
TOTAL                159     55416.     (RANDOM EFFECTS STATISTICS)

ETA= .2679  ETA-SOR= .0719  (VAR COMP= 24.892  %VAR AMONG= 7.02)

LEVEL          N     MEAN     VARIANCE    STD DEV

100%          40   34.829     460.94      21.470
75%           40   37.884     392.65      19.815
50%           40   31.250     311.98      17.663
25%           40   24.499     153.40      12.385

GRAND        160   32.115     348.53      18.669
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UNIVARIATE 1-WAY ANOVA  CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 5.LEGFL   N= 80 0JT OF 80

SOURCE                DF  SUM OF SORS   MEAN SOR   F-STATISTIC  SIGNIF

BETWEEN                3     2564.4      854.81      2.8411      .0434
WITHIN                76     22866.      300.87
TOTAL                 79     25431.     (RANDOM EFFECTS STATISTICS)

ETA= .3176  ETA-SOR= .1008  (VAR COMP= 27.697  %VAR AMONG= 8.43)

LEVEL          N     MEAN     VARIANCE    STD DEV

100%          20   30.519     328.93      18.136
75%           20   40.781     308.41      17.562
50%           20   32.747     393.84      19.845
25%           20   25.025     172.31      13.127

GRAND         80   32.268     321.91      17.942
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UNIVARIATE 1-WAY ANOVA  CASES=SEX:MALE

ANALYSIS OF VAPIANCE OF 5.LEGFL   N= 80 OUT OF 80

SOURCE                DF  SUM OF SORS   MEAN SOR   F-STATISTIC  SIGNIF

BETWEEN                3     2587.5      862.49      2.3928      .0750
WITHIN                76     27394.      360.45
TOTAL                 79     29982.     (RANDOM EFFECTS STATISTICS)

ETA= .2938  ETA-SOR= .0863  (VAR COMP= 25.102  %VAR AMONG= 6.51)

LEVEL          N     MEAN     VARIANCE    STD DEV

100%          20   39.139     578.11      24.044
75%           20   34.988     479.90      21.907
50%           20   29.752     241.82      15.551
25%           20   23.977     141.98      11.915

GRAND         80   31.963     379.52      19.481
```

Table 18 - Peak Level Exertion Component (based upon 100% exertion level average) ANOVA for Leg Flexion

```
<ANOVA VAR=4,5,6,7 CASES=1-160 STRAT=V3>

UNIVARIATE 1-WAY ANOVA  CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 4.LEGEX  N= 160 OUT OF 160

SOURCE                 DF SUM OF SQRS  MEAN SQR  F-STATISTIC SIGNIF

BETWEEN                 3    4470.9     1490.3     6.0484      .0006
WITHIN                156    38437.     246.39
TOTAL                 159    42908.     (RANDOM EFFECTS STATISTICS)

ETA= .3228  ETA-SQR= .1042  (VAR COMP= 31.097  %VAR AMONG= 11.21)

LEVEL          N     MEAN    VARIANCE   STD DEV

100%          40   36.663     489.74     22.130
75%           40   31.788     233.89     15.294
50%           40   27.928     142.58     11.941
25%           40   22.230     119.36     10.925

GRAND        160   29.652     269.86     16.428
-----------------------------------------------------------------------
     MEANPEAK
<ANOVA VAR=4,5,6,7 CASES=V2:1 STRAT=V3>

UNIVARIATE 1-WAY ANOVA  CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 4.LEGEX  N= 80 OUT OF 80

SOURCE                 DF SUM OF SQRS  MEAN SQR  F-STATISTIC SIGNIF

BETWEEN                 3    3920.0     1306.7     4.7756      .0042
WITHIN                 76    20795.     273.61
TOTAL                  79    24715.     (RANDOM EFFECTS STATISTICS)

ETA= .3983  ETA-SQR= .1586  (VAR COMP= 51.653  %VAR AMONG= 15.88)

LEVEL          N     MEAN    VARIANCE   STD DEV

100%          20   40.371     562.57     23.719
75%           20   34.199     317.53     17.819
50%           20   26.384     117.50     10.840
25%           20   22.236     96.854     9.8415

GRAND         80   30.798     312.84     17.687
-----------------------------------------------------------------------
<ANOVA VAR=4,5,6,7 CASES=V2:2 STRAT=V3>

UNIVARIATE 1-WAY ANOVA  CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 4.LEGEX  N= 80 OUT OF 80

SOURCE                 DF SUM OF SQRS  MEAN SQR  F-STATISTIC SIGNIF

BETWEEN                 3    1219.9     406.30     1.8419      .1467
WITHIN                 76    16765.     220.59
TOTAL                  79    17984.     (RANDOM EFFECTS STATISTICS)

ETA= .2603  ETA-SQR= .0678  (VAR COMP= 9.2953  %VAR AMONG= 4.04)

LEVEL          N     MEAN    VARIANCE   STD DEV

100%          20   32.954     413.71     20.340
75%           20   29.376     150.33     12.261
50%           20   29.471     170.16     13.044
25%           20   22.723     148.14     12.171

GRAND         80   28.906     227.64     15.088
```

<u>Table 19</u> - Peak Level Exertion Component (based upon 100% exertion level average) ANOVA for Leg Extension

UNIVARIATE 1-WAY ANOVA CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 6.ELBOW N= 160 OUT OF 160

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	3291.0	1097.0	3.7375	.0125
WITHIN	156	45788.	293.51		
TOTAL	159	49079.	(RANDOM EFFECTS STATISTICS)		

ETA= .2590 ETA-SQR= .0671 (VAR COMP= 20.057 %VAR AMONG= 6.41)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	40	29.780	513.51	22.661
75%	40	34.387	214.79	14.656
50%	40	30.928	271.35	16.473
25%	40	21.962	174.41	13.206
GRAND	160	29.739	308.67	17.569

UNIVARIATE 1-WAY ANOVA CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 6.ELBOW N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	3346.6	1115.5	3.2215	.0273
WITHIN	76	26317.	346.28		
TOTAL	79	29664.	(RANDOM EFFECTS STATISTICS)		

ETA= .3359 ETA-SQR= .1128 (VAR COMP= 39.462 %VAR AMONG= 10.00)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	38.851	665.80	25.803
75%	20	35.239	199.67	14.131
50%	20	31.287	341.51	18.480
25%	20	21.526	178.14	13.347
GRAND	80	31.726	375.49	19.378

UNIVARIATE 1-WAY ANOVA CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 6.ELBOW N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	2291.3	763.75	3.5975	.0173
WITHIN	76	16135.	212.30		
TOTAL	79	18426.	(RANDOM EFFECTS STATISTICS)		

ETA= .3526 ETA-SQR= .1243 (VAR COMP= 27.573 %VAR AMONG= 11.49)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	20.709	215.02	14.663
75%	20	33.934	239.69	15.482
50%	20	30.369	215.04	14.664
25%	20	22.397	179.46	13.396
GRAND	80	26.757	233.24	15.272

Table 20 - Peak Level Exertion Component (based upon 100% exertion level average) ANOVA for Elbow Flexion

UNIVARIATE 1-WAY ANOVA CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 7.FINGER N= 160 OUT OF 160

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	8474.6	2824.9	3.6035	.0149
WITHIN	156	.12229 +6	783.93		
TOTAL	159	.13077 +6	(RANDOM EFFECTS STATISTICS)		

ETA= .2546 ETA-SQR= .0648 (VAR COMP= 51.023 %VAR AMONG= 6.11)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	40	45.368	1379.8	37.146
75%	40	40.830	706.77	26.585
50%	40	35.654	666.49	25.817
25%	40	25.802	382.67	19.562
GRAND	160	36.914	822.44	28.678

SINK PREVIOUS

UNIVARIATE 1-WAY ANOVA CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 7.FINGER N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	5599.5	1866.5	1.8732	.1413
WITHIN	76	75729.	996.44		
TOTAL	79	81329.	(RANDOM EFFECTS STATISTICS)		

ETA= .2624 ETA-SQR= .0689 (VAR COMP= 43.503 %VAR AMONG= 4.18)

LEVEL	N	MEAN	VARIANCE	STD DEV

UNIVARIATE 1-WAY ANOVA CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 7.FINGER N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	5193.6	1731.2	3.1047	.0315
WITHIN	76	42378.	557.61		
TOTAL	79	47572.	(RANDOM EFFECTS STATISTICS)		

ETA= .3304 ETA-SQR= .1092 (VAR COMP= 58.680 %VAR AMONG= 9.52)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	45.051	1453.1	38.120
75%	20	37.022	342.03	18.494
50%	20	26.164	115.94	10.768
25%	20	25.751	319.36	17.871
GRAND	80	33.497	602.18	24.539

<u>Table 21</u> - Peak Level Exertion Component (based upon 100% exertion level average) ANOVA for Finger Flexion

Percentages Based Upon the Maximal Strength Exertion

The results of ANOVAs analyzing the maintained portion of the strength are shown in Tables 22 through 25. They concern the group as a whole and each sex grouping, for LF, LE, EF, and FF. The group ANOVA indicates significant variability differences for each type of exertion ($F_{LF} = 4.25$, $F_{LE} = 10.23$, $F_{EF} = 4.70$, $F_{FF} = 13.01$, d.f. = 3/156, $p \leq .01$). As in the previous section, the LE, EF and FF exertions indicate a pattern of increased variability as the exertion level increases. The female group exhibited significant ANOVAs for the LE, EF, and FF types of exertion ($F_{LE} = 7.04$, $F_{EF} = 6.25$, $F_{FF} = 9.61$, d.f. = 3/76, $p \leq .01$) with similar variability pattern trends. The only significant F-statistic for the male group which exhibited this pattern was found for the FF type of exertion ($F_{FF} = 4.76$, d.f. = 3/76, $p \leq .01$).

Thus, the same groups showed significant results in these ANOVAs based on the maximal strength scores, as were previously found with the data based upon the average scores.

UNIVARIATE 1-WAY ANOVA CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 5.LEGFL N= 160 OUT OF 160

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	3018.1	1006.0	4.2269	.0066
WITHIN	156	37129.	238.00		
TOTAL	159	40147.	(RANDOM EFFECTS STATISTICS)		

ETA= .2742 ETA-SQR= .0752 (VAR COMP= 19.201 %VAR AMONG= 7.47)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	40	30.374	277.36	16.654
75%	40	33.911	316.52	17.791
50%	40	28.272	230.85	15.194
25%	40	21.967	127.28	11.282
GRAND	160	28.631	252.50	15.890

UNIVARIATE 1-WAY ANOVA CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 5.LEGFL N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	2115.8	705.26	3.1012	.0316
WITHIN	76	17284.	227.42		
TOTAL	79	19400.	(RANDOM EFFECTS STATISTICS)		

ETA= .3302 ETA-SQR= .1091 (VAR COMP= 23.892 %VAR AMONG= 9.51)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	27.602	197.45	14.052
75%	20	37.430	263.96	16.247
50%	20	29.628	285.29	16.891
25%	20	23.232	162.98	12.766
GRAND	80	29.473	245.56	15.670

UNIVARIATE 1-WAY ANOVA CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 5.LEGFL N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	1729.3	576.42	2.3173	.0823
WITHIN	76	18905.	248.74		
TOTAL	79	20634.	(RANDOM EFFECTS STATISTICS)		

ETA= .2895 ETA-SQR= .0838 (VAR COMP= 16.384 %VAR AMONG= 6.18)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	33.146	355.70	18.860
75%	20	30.391	359.67	18.965
50%	20	26.916	184.68	13.590
25%	20	20.702	94.922	9.7428
GRAND	80	27.789	261.19	16.161

Table 22 - Maintained Level Exertion Component (based upon greatest exertion) ANOVA for Leg Flexion

<ANOVA VAR=4,5,6,7 CASES=1-160 STRAT=V3>

UNIVARIATE 1-WAY ANOVA CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 4.LEGEX N= 160 OUT OF 160

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	4405.7	1468.6	10.235	.0000
WITHIN	156	22384.	143.49		
TOTAL	159	26790.	(RANDOM EFFECTS STATISTICS)		

ETA= .4055 ETA-SQR= .1645 (VAR COMP= 33.127 %VAR AMONG= 18.76)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	40	32.565	255.99	16.000
75%	40	27.000	122.79	11.081
50%	40	24.075	109.26	10.453
25%	40	18.018	85.915	9.2690
GRAND	160	25.415	168.49	12.980

<ANOVA VAR=4,5,6,7 CASES=V2:1 STRAT=V3>

UNIVARIATE 1-WAY ANOVA CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 4.LEGEX N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	3114.0	1038.0	7.0366	.0003
WITHIN	76	11211.	147.51		
TOTAL	79	14325.	(RANDOM EFFECTS STATISTICS)		

ETA= .4662 ETA-SQR= .2174 (VAR COMP= 44.574 %VAR AMONG= 23.19)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	34.840	304.05	17.437
75%	20	27.908	124.51	11.159
50%	20	23.519	100.97	10.048
25%	20	17.769	60.515	7.7791
GRAND	80	26.009	181.33	13.466

<ANOVA VAR=4,5,6,7 CASES=V2:2 STRAT=V3>

UNIVARIATE 1-WAY ANOVA CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 4.LEGEX N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	1490.0	496.68	3.4573	.0205
WITHIN	76	10918.	143.66		
TOTAL	79	12408.	(RANDOM EFFECTS STATISTICS)		

ETA= .3465 ETA-SQR= .1201 (VAR COMP= 17.651 %VAR AMONG= 10.94)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	30.290	210.50	14.509
75%	20	26.091	125.79	11.216
50%	20	24.691	172.65	11.075
25%	20	18.260	115.71	10.757
GRAND	80	24.820	157.07	12.539

Table 23 - Maintained Level Exertion Component (based upon greatest exertion) ANOVA for Leg Extension

UNIVARIATE 1-WAY ANOVA CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 6.ELBOW N= 160 OUT OF 160

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	3431.2	1143.7	4.7007	.0036
WITHIN	156	37957.	243.31		
TOTAL	159	41388.	(RANDOM EFFECTS STATISTICS)		

ETA= .2879 ETA-SQR= .0829 (VAR COMP= 22.510 %VAR AMONG= 8.47)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	40	30.498	515.17	22.697
75%	40	25.513	183.23	13.536
50%	40	24.233	184.00	13.565
25%	40	17.520	90.850	9.5315
GRAND	160	24.441	260.30	16.134

UNIVARIATE 1-WAY ANOVA CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 6.ELBOW N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	5121.8	1707.3	6.2514	.0008
WITHIN	76	20756.	273.10		
TOTAL	79	25877.	(RANDOM EFFECTS STATISTICS)		

ETA= .4449 ETA-SQR= .1979 (VAR COMP= 71.705 %VAR AMONG= 20.80)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	38.643	640.70	25.312
75%	20	27.399	214.05	14.631
50%	20	23.284	169.47	13.018
25%	20	16.627	68.173	8.2567
GRAND	80	26.488	327.56	18.098

UNIVARIATE 1-WAY ANOVA CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 6.ELBOW N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	502.73	167.58	.88830	.4512
WITHIN	76	14337.	188.65		
TOTAL	79	14840.	(RANDOM EFFECTS STATISTICS)		

ETA= .1841 ETA-SQR= .0339 (VAR COMP= -1.0536 %VAR AMONG= -0.)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	22.353	277.09	16.646
75%	20	23.627	154.57	12.432
50%	20	25.182	206.31	14.364
25%	20	18.414	116.63	10.799
GRAND	80	22.394	187.85	13.706

Table 24 - Maintained Level Exertion Component (based upon *greatest exertion) ANOVA for Elbow Flexion*

```
UNIVARIATE 1-WAY ANOVA  CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 7.FINGER  N= 160 OUT OF 160

SOURCE              DF SUM OF SQRS  MEAN SQR  F-STATISTIC SIGNIF

BETWEEN              3   12976.      4325.3     13.009      .0000
WITHIN             156   51868.      332.48
TOTAL              159   64844.     (RANDOM EFFECTS STATISTICS)

ETA= .4473  ETA-SQR= .2001  (VAR COMP= 99.821  %VAR AMONG= 23.09)

LEVEL         N     MEAN     VARIANCE    STD DEV

100%         40   43.581     544.15      23.327
75%          40   32.649     264.15      16.253
50%          40   26.027     304.80      17.459
25%          40   19.153     216.84      14.725

GRAND       160   30.353     407.82      20.195
SINK PREVIOUS
```

```
UNIVARIATE 1-WAY ANOVA  CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 7.FINGER  N= 80 OUT OF 80

SOURCE              DF SUM OF SQRS  MEAN SQR  F-STATISTIC SIGNIF

BETWEEN              3    9289.8     3096.6     9.6084      .0000
WITHIN              76   24493.      322.28
TOTAL               79   33783.     (RANDOM EFFECTS STATISTICS)

ETA= .5244  ETA-SQR= .2750  (VAR COMP= 138.72  %VAR AMONG= 30.09)

LEVEL         N     MEAN     VARIANCE    STD DEV

100%         20   48.782     325.03      18.029
75%          20   35.066     326.72      18.075
50%          20   31.520     443.99      21.071
25%          20   18.514     193.37      13.906

GRAND        80   33.471     427.63      20.679
```

```
UNIVARIATE 1-WAY ANOVA  CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 7.FINGER  N= 80 OUT OF 80

SOURCE              DF SUM OF SQRS  MEAN SQR  F-STATISTIC SIGNIF

BETWEEN              3    4669.6     1556.5     4.7633      .0043
WITHIN              76   24835.      326.78
TOTAL               79   29505.     (RANDOM EFFECTS STATISTICS)

ETA= .3978  ETA-SQR= .1583  (VAR COMP= 61.488  %VAR AMONG= 15.86)

LEVEL         N     MEAN     VARIANCE    STD DEV

100%         20   38.379     734.95      27.110
75%          20   30.231     203.17      14.254
50%          20   20.934     119.13      10.869
25%          20   19.792     250.06      15.838

GRAND        80   27.234     373.48      19.326
```

Table 25 - Maintained Level Exertion Component (based upon greatest exertion) ANOVA for Finger Flexion

An interesting contrast to these findings based on maintained levels appears when reviewing the ANOVA results which analyze the peak portion of the exertion. Unlike with the maintained level scores, more significant F-statistics appear for the peak portion of the exertion when it was based upon the maximum exertion than when based upon each subject's 100% level average. These peak sensitive ANOVAs for the group data and for each sex groupings for LF, LE, EF, and FF appear in Tables 26 through 29. Significant F-statistics were found for the group data for each type of exertion (F_{LF} = 4.21, F_{LE} = 6.35, F_{EF} = 4.08, F_{FF} = 4.03, d.f. = 3/156, $p \leqq .01$). However, only the LE and FF types of exertion indicated the previously found patter of increasing variability at increasing levels. When the data were analyzed by sex the female group showed a significant F-ratio for the LE exertion (F_{LE} = 5.08, d.f. = 3/76, $p \leqq .01$) which did indicate the same variability pattern. The male group produced a significant F-statistic for the FF exertion (F_{ff} = 4.23, d.f. = 3/76, $p \leqq .01$) however the variability pattern in this case was unclear.

ANALYSIS OF VARIANCE OF 5.LEGFL N= 160 OUT OF 160

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	2999.1	999.70	4.2122	.0068
WITHIN	156	37024.	237.33		
TOTAL	159	40023.	(RANDOM EFFECTS STATISTICS)		

ETA= .2737 ETA-SQR= .0749 (VAR COMP= 19.059 %VAR AMONG= 7.43)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	40	30.138	291.13	17.063
75%	40	33.783	304.72	17.456
50%	40	27.774	229.90	15.162
25%	40	21.874	123.58	11.117
GRAND	160	28.392	251.72	15.866

UNIVARIATE 1-WAY ANOVA CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 5.LEGFL N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	2154.3	718.12	3.1213	.0308
WITHIN	76	17485.	230.07		
TOTAL	79	19640.	(RANDOM EFFECTS STATISTICS)		

ETA= .3312 ETA-SQR= .1097 (VAR COMP= 24.402 %VAR AMONG= 9.59)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	26.963	223.41	14.947
75%	20	37.010	254.63	15.957
50%	20	29.484	292.17	17.093
25%	20	22.741	150.08	12.251
GRAND	80	29.050	248.60	15.767

UNIVARIATE 1-WAY ANOVA CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 5.LEGFL N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	1742.6	580.86	2.3770	.0765
WITHIN	76	18572.	244.36		
TOTAL	79	20314.	(RANDOM EFFECTS STATISTICS)		

ETA= .2929 ETA-SQR= .0858 (VAR COMP= 16.825 %VAR AMONG= 6.44)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	33.312	352.95	18.787
75%	20	30.555	348.93	18.680
50%	20	26.063	173.56	13.174
25%	20	21.006	102.01	10.100
GRAND	80	27.734	257.14	16.036

<u>Table 26</u> - Peak Exertion Component (based upon greatest exertion) ANOVA for Leg Flexion

<ANOVA VAR=4,5,6,7 CASES=1-160 STRAT=V3>

UNIVARIATE 1-WAY ANOVA CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 4.LEGEX N= 160 OUT OF 160

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	2827.5	942.50	6.3506	.0004
WITHIN	156	23152.	148.41		
TOTAL	159	25980.	(RANDOM EFFECTS STATISTICS)		

ETA= .3299 ETA-SQR= .1088 (VAR COMP= 19.852 %VAR AMONG= 11.80)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	40	30.807	246.74	15.708
75%	40	27.564	149.49	12.227
50%	40	24.541	112.32	10.598
25%	40	19.388	85.107	9.2253
GRAND	160	25.575	163.40	12.783

<ANOVA VAR=4,5,6,7 CASES=V2:1 STRAT=V3>

UNIVARIATE 1-WAY ANOVA CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 4.LEGEX N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	2396.5	798.84	5.0871	.0029
WITHIN	76	11935.	157.03		
TOTAL	79	14331.	(RANDOM EFFECTS STATISTICS)		

ETA= .4089 ETA-SQR= .1672 (VAR COMP= 32.090 %VAR AMONG= 16.97)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	33.516	251.91	15.872
75%	20	29.362	200.22	14.150
50%	20	23.147	107.22	10.356
25%	20	19.339	68.785	8.2937
GRAND	80	26.341	181.41	13.469

<ANOVA VAR=4,5,6,7 CASES=V2:2 STRAT=V3>

UNIVARIATE 1-WAY ANOVA CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 4.LEGEX N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	837.58	279.19	1.9799	.1241
WITHIN	76	10717.	141.02		
TOTAL	79	11555.	(RANDOM EFFECTS STATISTICS)		

ETA= .2692 ETA-SQR= .0725 (VAR COMP= 6.9088 %VAR AMONG= 4.67)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	28.099	239.10	15.463
75%	20	25.767	99.820	9.9910
50%	20	25.935	119.24	10.920
25%	20	19.436	105.90	10.291
GRAND	80	24.809	146.26	12.094

Table 27 - Peak Exertion Component (based upon greatest exertion) ANOVA for Leg Extension

UNIVARIATE 1-WAY ANOVA CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 6.ELBOW N= 160 OUT OF 160

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	2628.1	876.05	4.0806	.0080
WITHIN	156	33491.	214.69		
TOTAL	159	36119.	(RANDOM EFFECTS STATISTICS)		

ETA= .2697 ETA-SQR= .0728 (VAR COMP= 16.534 %VAR AMONG= 7.15)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	40	25.799	323.43	17.984
75%	40	31.130	176.26	13.276
50%	40	27.805	213.70	14.618
25%	40	19.982	145.36	12.057
GRAND	160	26.179	227.17	15.072

UNIVARIATE 1-WAY ANOVA CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 6.ELBOW N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	2187.1	729.02	2.9627	.0374
WITHIN	76	18701.	246.07		
TOTAL	79	20888.	(RANDOM EFFECTS STATISTICS)		

ETA= .3236 ETA-SQR= .1047 (VAR COMP= 24.148 %VAR AMONG= 8.94)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	33.037	406.18	20.154
75%	20	31.274	165.02	12.846
50%	20	27.534	254.25	15.945
25%	20	19.446	158.82	12.602
GRAND	80	27.823	264.41	16.261

UNIVARIATE 1-WAY ANOVA CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 6.ELBOW N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	2119.7	706.55	4.2351	.0080
WITHIN	76	12679.	166.83		
TOTAL	79	14799.	(RANDOM EFFECTS STATISTICS)		

ETA= .3785 ETA-SQR= .1432 (VAR COMP= 26.986 %VAR AMONG= 13.92)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	18.561	147.41	12.141
75%	20	30.986	196.73	14.026
50%	20	28.077	184.24	13.574
25%	20	20.518	138.94	11.787
GRAND	80	24.536	187.33	13.687

Table 28 - Peak Exertion Component (based upon greatest exertion) ANOVA for Elbow Flexion

UNIVARIATE 1-WAY ANOVA CASES=CASE#:1-160

ANALYSIS OF VARIANCE OF 7.FINGER N= 160 OUT OF 160

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	4997.7	1665.9	4.0347	.0085
WITHIN	156	64412.	412.90		
TOTAL	159	69409.	(RANDOM EFFECTS STATISTICS)		

ETA= .2683 ETA-SQR= .0720 (VAR COMP= 31.325 %VAR AMONG= 7.05)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	40	36.442	619.91	24.899
75%	40	34.779	395.42	19.885
50%	40	30.214	356.49	18.881
25%	40	22.028	279.77	16.726
GRAND	160	30.966	436.54	20.893

SINK PREVIOUS

UNIVARIATE 1-WAY ANOVA CASES=SEX:FEMALE

ANALYSIS OF VARIANCE OF 7.FINGER N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	3654.1	1218.0	2.4303	.0717
WITHIN	76	38091.	501.19		
TOTAL	79	41745.	(RANDOM EFFECTS STATISTICS)		

ETA= .2959 ETA-SQR= .0875 (VAR COMP= 39.842 %VAR AMONG= 6.67)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	37.094	654.06	25.575
75%	20	37.333	526.60	22.948
50%	20	37.714	519.70	22.797
25%	20	21.781	304.40	17.447
GRAND	80	33.481	528.41	22.987

UNIVARIATE 1-WAY ANOVA CASES=SEX:MALE

ANALYSIS OF VARIANCE OF 7.FINGER N= 80 OUT OF 80

SOURCE	DF	SUM OF SQRS	MEAN SQR	F-STATISTIC	SIGNIF
BETWEEN	3	2780.4	926.82	2.9608	.0375
WITHIN	76	23790.	313.03		
TOTAL	79	26571.	(RANDOM EFFECTS STATISTICS)		

ETA= .3235 ETA-SQR= .1046 (VAR COMP= 30.689 %VAR AMONG= 8.93)

LEVEL	N	MEAN	VARIANCE	STD DEV
100%	20	35.791	617.50	24.850
75%	20	32.224	271.31	16.472
50%	20	22.713	93.585	9.6739
25%	20	22.275	269.72	16.423
GRAND	80	28.251	336.36	18.340

Table 29 - Peak Exertion Component (based upon greatest exertion) ANOVA for Finger Flexion

(C) Slope - Strength Analysis

Each subject's correlation coefficient of slope versus the percentage of strength for LF, LE, EF and FF is presented in Tables 30 through 33. Every table contains two correlation coefficients for each subject: one related to the percentage of strength in the maintained portion of the exertion, the other related to the peak portion of the exertion. The correlation coefficients between slope and maintained force were practically the same whether average maintained force or maximal maintained force were used as base values for the calculation of percentages. The same held true for the correlations between slope and peak percentages.

As the tables indicate, the correlation coefficients for the maintained and peak portions of the exertion follow each other rather closely. For the LF exertion 36 subjects produced significant correlation coefficients under each measure. Of those failing to produce significant values two were male and two were female. The average correlation coefficient for the group was .790 for both the maintained and peaks components of the exertion. For the LE exertion six out of 40 subjects (one male, five female) failed to produce significant correlations in the maintained condition while seven out of 40 (two male, five female) subjects failed to produce significant peak values. The group correlation coefficient average for the maintained level component was .810, versus .785 for the peak component. Within the EF type of exertion only one (male) subject out of 40 did not produce a significant value (maintained and peak) and most values under this exertion were rather high by comparison. This EF type of exertion produced the highest group correlation coefficient for both the maintained level (.850), and the peak (.870) components of the exertion. In the FF exertion only male subjects (three for the maintained condition and two for the peak condition) failed to produce significant correlation coefficients. This condition produced the second highest group correlation coefficient for both maintained (.835) and peak (.860) components. One subject performed poorly in all types of exertion.

The trend in these analyses seems to indicate that the more finely tuned the muscle group tested, the higher the correlation coefficient: arms and fingers are used preferably for tasks requiring accuracy, whereas legs are generally used to produce brute force and power. The group correlation coefficients (normalized for Z scores, all significant) were as follows:

Maintained

$\bar{r}_{LF} = .790$, $\bar{r}_{LE} = .810$, $\bar{r}_{EF} = .850$, $\bar{r}_{FF} = .835$; and

Peak

$\bar{r}_{LF} = .790$, $\bar{r}_{LE} = .785$, $\bar{r}_{EF} = .870$; $r_{FF} = .860$;

each with

d.f. = 40, $p \leq .01$.

Subject	Maintained		Peak	
	r	Z	r	Z
1	.5919	.678	.5965	.685
2	.9071	1.499	.8976	1.447
3	.7683	1.008	.7926	1.071
4	.5932	.685	.5836	.670
5	.5198*	.576	.5214*	.576
6	.8419	1.221	.8280	1.172
7	.6109	.709	.6269	.733
8	.7762	1.033	.7832	1.058
9	.6407	.758	.6149	.725
10	.6830	.838	.7004	.867
11	.9638	2.014	.9535	1.886
12	.9817	2.298	.9831	2.443
13	.6826	.838	.6900	.848
14	.5953	.685	.5978	.693
15	.8120	.709	.7762	1.033
16	.5043*	.556	.5144*	.570
17	.7780	1.045	.7791	1.045
18	.8165	1.143	.8251	1.172
19	.3942*	.418	-.1911*	.120
20	.9310	1.658	.9257	1.623
21	.7566	.984	.7556	.984
22	.7662	1.008	.7645	1.008
23	.9175	1.557	.9210	1.589
24	.3332*	.343	.3349*	.348
25	.8105	1.127	.8142	1.142
26	.8350	1.204	.8294	1.188
27	.8028	1.099	.7758	1.033
28	.9098	1.528	.9073	1.528
29	.5618	.633	.5706	.715
30	.8095	1.127	.8147	1.142
31	.7827	1.058	.7754	1.033
32	.8811	1.376	.8829	1.398
33	.7503	.973	.7469	.973
34	.8992	1.472	.9015	1.472
35	.7897	1.071	.7931	1.085
36	.6249	.733	.6120	.709
37	.9745	2.185	.9762	2.185
38	.6572	.784	.6771	.802
39	.8633	1.313	.8487	1.256
40	.6858	.838	.7431	.962
$\bar{Z}_r$		1.069		1.068
Grand $\bar{r}$	0.790		.790	

* = not significant
(r_{crit} = 0.542; df. = 16; $p < .01$)

Table 30 - Correlation Coefficients and Z Transformations for the Components of Leg Flexion

Subject	Maintained		Peak	
	r	Z	r	Z
1	.6981	.867	.7098	.867
2	.8217	1.157	.8236	1.172
3	.4426*	.485	.4276*	.454
4	.1971*	.203	.1788*	.182
5	.6369	.741	.6454	.478
6	-.0843*	-.084	-.0775*	-.077
7	.6912	.848	.6976	.858
8	.9430	1.783	.9401	1.738
9	.6211	.725	.6327	.750
10	.7199	.908	.7989	1.099
11	.7936	1.058	.7837	1.058
12	.9095	1.528	.9066	1.528
13	.8457	1.256	.8421	1.221
14	.8696	1.333	.8752	.1354
15	.7406	.950	.7456	.962
16	.4275*	.454	.4411*	.472
17	.7922	1.071	.7760	1.033
18	.4631*	.504	.4083*	.436
19	.9821	2.298	-.0272*	-.027
20	.5415	.604	.5330*	.597
21	.7742	1.033	.7718	1.020
22	.8636	1.313	.8732	1.354
23	.9261	1.623	.9223	1.589
24	.7526	.973	.7455	.962
25	.9225	1.589	.9239	1.623
26	.8460	1.238	.8437	1.238
27	.9891	2.647	.9916	2.647
28	.7932	1.085	.7877	1.058
29	.9036	1.499	.8800	1.376
30	.6401	.758	.6587	.793
31	.7963	1.085	.7941	1.085
32	.8406	1.221	.7806	1.045
33	.9337	1.697	.9300	1.658
34	.8055	1.113	.8068	1.113
35	.9085	1.528	.9062	1.499
36	.8998	1.472	.8988	1.472
37	.8500	1.256	.8532	1.274
38	.4138*	.442	.4085	.436
39	.9576	1.886	.9449	1.832
40	.6861	.838	.7204	.908
$\bar{Z}_r$		1.124		1.053
Grand $\bar{r}$	.810		.785	

* = not significant
(r_{crit} = 0.542; df. = 16; $p < .01$)

Table 31 - Correlation Coefficients and Z Transformations for the Components of Leg Extension

Subject	Maintained r	Maintained Z	Peak r	Peak Z
1	.8742	1.354	.8858	1.398
2	.7010	.867	.7434	.962
3	.9082	1.528	.8982	1.472
4	.7792	1.045	.7384	.950
5	.8825	1.376	.9014	1.472
6	.7554	.984	.8605	1.293
7	.8847	1.398	.8681	1.333
8	.8394	1.221	.9402	1.738
9	.5894	.678	.7149	.897
10	.7539	.984	.8631	1.313
11	.9224	1.589	.9435	1.783
12	.9700	2.092	.9620	1.946
13	.9355	1.697	.9186	1.589
14	.7983	1.099	.7387	.950
15	.9343	1.204	.9400	1.738
16	.8040	1.113	.8235	1.172
17	.8820	1.376	.8362	1.204
18	.8618	1.293	.8697	1.333
19	-.0292*	-.029	-.3012*	-.310
20	.8584	1.293	.8569	1.274
21	.9088	1.528	.9131	1.557
22	.9145	1.557	.9300	1.658
23	.9139	1.557	.9541	1.886
24	.8761	1.354	.9082	1.528
25	.8592	1.293	.8987	1.472
26	.9408	1.738	.9485	1.832
27	.8479	1.256	.8399	1.188
28	.7669	1.008	.8012	1.099
29	.9164	1.557	.8829	1.398
30	.7823	1.045	.7794	1.045
31	.7272	.918	.7452	.962
32	.6383	.758	.7801	1.045
33	.9197	1.589	.9261	1.623
34	.8404	1.221	.8642	1.313
35	.8672	1.313	.8849	1.398
36	.7311	.929	.8500	1.256
37	.8959	1.447	.8996	1.472
38	.7764	1.033	.8116	1.127
39	.9286	1.658	.9213	1.589
40	.8900	1.422	.8552	1.274
$\bar{Z}_r$		1.258		1.331
Grand $\bar{\bar{r}}$	.850		.870	

* = not significant
(r_{crit} = 0.542; df. = 16; $p < .01$)

Table 32 - Correlative Coefficients and Z Transformations for the Components of Elbow Flexion

Subject	Maintained r	Maintained Z	Peak r	Peak Z
1	.8439	1.238	.7636	1.008
2	.9271	1.623	.9256	1.623
3	.0893*	.089	.0898*	.090
4	.6823	.829	.7327	.940
5	.5133*	.570	.6140	.717
6	.8729	1.354	.8906	1.422
7	.7709	1.020	.7722	1.020
8	.7803	1.045	.8673	1.313
9	.7341	.940	.7732	1.033
10	.9034	1.499	.9109	1.528
11	.8947	1.447	.9079	1.528
12	.9448	1.783	.9646	2.014
13	.8506	1.256	.8386	1.221
14	.6893	.848	.8148	1.142
15	.8887	1.422	.9042	1.499
16	.8273	1.172	.8084	1.127
17	.9457	1.783	.8731	1.354
18	.9324	1.658	.9346	1.697
19	-.1206*	-.121	-.0690*	-.069
20	.8700	1.333	.8432	1.238
21	.8305	1.188	.8324	1.188
22	.7317	.929	.9234	1.623
23	.9427	1.783	.9245	1.623
24	.7526	.984	.8237	1.172
25	.8403	1.221	.8798	1.376
26	.7457	.962	.8506	1.256
27	.8490	1.256	.8148	1.142
28	.7746	1.033	.8258	1.172
29	.8048	1.113	.8356	1.204
30	.8123	1.127	.8690	1.333
31	.9288	1.658	.9578	1.886
32	.7303	.929	.7384	.950
33	.7115	.887	.7240	.918
34	.7993	1.099	.8066	1.113
35	.8842	1.398	.9082	1.528
36	.6699	.811	.7940	1.085
37	.8923	1.422	.9165	1.557
38	.9644	2.014	.9830	2.443
39	.9725	2.185	.9537	1.886
40	.9197	1.589	.9242	1.623
$\bar{Z}_r$		1.209		1.288
Grand $\bar{r}$		.835		.860

* = not significant
(r_{crit} = 0.542; df. = 16; p < .01)

Table 33 - Correlative Coefficients and Z Transformations for the Components of Finger Flexion

DISCUSSION

The results displayed in the preceding tables may be interpreted as follows.

With respect to group behavior, males tended to exert smaller percentages at the requested levels labeled 75, 50 and 25% than females, as compared to their exertions exhibited at the 100% level. This holds true for the mean values of leg flexion, leg extension, and elbow flexion, but the opposite is apparent for finger flexion. While no definite explanation for this phenomenon is offered here, one might speculate that it is related to the regulation of muscle strength exertions (to be discussed later in this section).

As usually found in strength tests, male subjects exerted altogether larger absolute forces than female subjects. In addition, males tended to achieve their force exertions in shorter periods of time than females. Again, no explanation for this phenomenon is offered. Regarding the mean values (whether based on maintained strength or peak exertions) the subjects were rather accurate in indeed exerting 50% of their strength when asked to do so, but exerted less than 75% and more than 25% when requested to exert 75% or 25%, respectively.

Regarding the variability of repeated strength scores at the levels requested, the results of this study confirm findings of previous experiments concerning elbow flexions (Kroemer 1979, Marras 1978, Marras & Kroemer 1979). With respect to elbow flexion, this study indicates the same findings as before, i.e., no variability pattern is related to levels of requested force exertion. In the experiments reported here, the same lack of trends was also found for the other strength exertions, namely finger flexion, leg flexion and leg extension. It is true that the null hypothesis was in several cases refuted by the analysis of the experimental data, in such that there were indeed several instances of significant differences in variability at several of the requested levels. However, the primary experimental hypothesis assuming increased variability with decreased levels of exertion was not supported. If trends existed at all, they tended to go in the opposite direction, i.e., more variability seemed to exist at higher levers of force exertion. Thus, in conclusion, the assumption of increasing variability with decreasing force levels (Beck and Hettinger 1956; Laurig, Rohmert, and Zipp 1975; Rohmert and Sieber 1960) was not supported by the analysis of the present experimental results. Recent experiments of the present authors (Marras 1978, Marras and Kroemer 1979) had also failed to support the earlier assumption.

With respect to the onset slope in relation to the actually achieved percentage of force, the data in this study also confirm previous findings of the same authors. High, positive and significant correlation coefficients between onset slope and percentage of strength exerted by elbow flexion had been found both when the experimental data were considered for the individual subjects, and for group means. This same result was found in this study for three more strength exertions, namely finger flexion, leg extension and leg flexion. Since Z transformations were used in the computations of the correlation coefficients for groups, the mean correlation coefficidents for the groups should be considered accurate and unbiased.

With respect to the use of either peak or maintained force data as inputs for the analysis, this study does not indicate any major differences in the interpretation of the data based on either procedure. This finding has two consequences:

> Even when using peak scores as data inputs, this study does not at all agree with earlier claims that larger variability occures at lower force levels; see above. There appears to be no reason to use peak readings instead of maintained level scores in experiments on muscle contractions performed according to the standardized test regimen (Caldwell et al. 1974).

With respect to the type of exertions, i.e., the body limbs and muscles used in the tests, some rather interesting speculations can be associated with the experimental findings, and related to the model of strength regulation (Kroemer 1979) explained earlier in this report. While all four types of exertions resulted in significant correlation coefficients between slopes and strength exertions, the highest correlations were found for finger and elbow flexion. Lower coefficients were associated with knee flexion and knee extension.

Motions, activities and strength exertions with the upper extremity are generally thought to be better controlled, and more finely tuned than with the lower extremity. Such control requires a highly developed feedback system such as described in the model of strength regulation. However, there seems to be a tradeoff reflected in the correlation coefficient between the tuning of the muscle and the power producing capabilities of the muscle. Future research may focus upon this observation and attempt to quantify the actual differences in correlation coefficients among exertion types.

In summary, the experiments indicate the following:

1. Experimental hypotheses number one and two appear acceptable on the basis of analysis of the data, while hypothesis number three is rejected.
2. The traditional notion that the level of strength exertion can be identified by the variability of repeated exertions can no longer be maintained. This study refutes again the assumption that larger variability should be expected at lower levels of strength capability exertion, and that minimal variability should be expected at maximal levels.
3. This study confirms earlier findings by the authors that the speed of strength formation is related to the portion of available muscle strength exerted. High correlation coefficients were found between the onset slope and the percentage of individual

force exerted. This finding promises to provide a technique to ascertain whether or not a subject performs at the maximum possible strength level. Furthermore, it might provide a technique to assess at what actual level of strength capability the exertion takes place.

SUMMARY AND CONCLUSIONS

Experiments were performed with 20 female and 20 male subjects in order to determine indicators of whether the subjects performed maximal or submaximal isometric strength exertions. The exertions tested were elbow flexion, finger flexion, knee flexion and knee extension. Subjects were instructed to perform repeated tests at 100, 75, 50 and 25% of their individual strength capabilities. However, no external controls were used to ensure exertions at these levels. The only performance measures used were analog recordings of the strength scores exerted on a static dynamometer.

In agreement with earlier related tests, the following was found:

1. The variability of tests scores in repeated exertions is not a viable indicator of the portion of individual strength exerted. In contrast to older assumptions, exertions at submaximal levels did not show larger variability than maximal exertions.
2. The buildup phase of strength exertion is a reliable indicator of the force level to be attained. Though different in its magnitude for each individual, the trend is obvious: submaximal strength exertions require a longer build-up phase. The steeper the strength formation curve, the stronger the following muscle strength exertion.

Accordingly, the onset slope of a muscle strength exertion, recorded at an external dynamometer, indicates the conformance of a subject with the instruction to perform a maximal insometric muscle strength exertion.

FUTURE RESEARCH NEEDS

(A) The experimental results show (in agreement with earlier studies of the same authors) that the formation of a strength contraction, i.e. the onset slope, is a reliable indicator of an individual's cooperation in exerting a maximal strength exertion. Though individually different, the results indicate that for any given subject, a relatively slow onset (flat angle) indicates a submaximal exertion, and a quick onset (steep angle) indicates a maximal effort. The steeper the angle, the closer the individual gets to his/her maximal exertion capability.

(B) As in the earlier studies, this research again has shown that the variability of scores exerted during the constant level phase of contraction is not a reliable indicator of a subject's comformance with the request to exert a maximum contraction. This finding is in contrast to earlier experimenters (Beck and Hettinger 1956, Rohmert and Sieber 1960) who, though on the basis of tests with one or very few subjects, concluded that at low levels of exertion large variability among repeated trials existed, while at maximum level the variability was small. The experiments reported here contradict this postulate rather conclusively. No systematic differences in variability were found at the different levels of submaximal and maximal strength exertion.

The findings regarding (A) the correlation between onset slope and portion of true strength exerted and (B) the variability of the constant phases, were similar when using as reference either the maintained phase of exertion, or the highest peak observed in each subject's performance. While the maintained level of performance has been used in earlier experiments by the authors, the consideration of the peak value is new in this research. Using the data of 40 subjects, of four different muscle groups, and of four exertions each at four force levels, peak or level values used as bases yielded basically the same results.

In the research reported here, the subjects were asked pointedly to increase their contraction to a level performance, and then to maintain this level for a few seconds. It is conceivable that if the underlying instructions to the subjects had been different, different results might have been obtained. For example, if subjects had been instructed to exert only their highest possible peak force (and not to maintain a level force) both onset slope and the variability of the peak values might have been different. In fact, it is probable that the earlier researchers cited above used such instructions for their subjects and thus arrived at different results.

Of course, one could argue that the regimen employed in the present study (Caldwell et al. 1974) should be only one to be considered because it is, de facto, the standard procedure. If one followed this line of thought, no further experiments would appear necessary at this point. However, if one wanted to argue that instructions to exert a peak force (jerking force) are easier to convey to subjects, and that one therefore should perform further experiments with such instructions, then related experiments would be desirable. In fact, they could be performed rather quickly and easily since all equipment is at hand, and all procedures are well tested.

REFERENCES

Astrand, P.O. and Rodahl, K., Textbook of Work Physiology, 2nd ed., New York, N.Y., McGraw-Hill, 1977.

Beck, W. and Hettinger, T., "Ist die Bewertung von Kraftmessungen bei der Begutachtung sinnvoll?" (Is the Evaluation of Strength Measurements Worthwhile for Medical Examinations?), Monatsschrift f. Unfallheilkunde, 59, 116-118, 1956.

Caldwell, L.S., Chaffin, D.B., Dukes-Dobos, F.N., Kroemer, K.H.E., Laubach, L.L., Snook, S.H., and Wasserman, D.E., "A Proposed Standard Procedure for Static Muscle Strength Testing", American Industrial Hygiene Association Journal, 35:4, 201-206, 1974.

Drury, C.G.(Ed.), Safety in Manual Materials Handling. DHEW (NIOSH) Publication No. 78-185, Washington DC, U.S. Government Printing Office, 1978.

Garrett, J.W., Anthropometry of the Hands of Male Air Force Flight Personnel, AMRL-TR-60-42. Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory, 1970.

Hettinger, T., Isometrisches Muskeltraining (Isometric Muscle Training), Stuttgart: Thieme, 1972.

Kroemer, K.H.E., "Human Strength: Terminology, Measurement and Interpretation of Data", Human Factors, 12:3, 297-313, 1970.

Kroemer, K.H.E., Designing for Muscular Strength of Various Populations, AMRL-TR-72-46, Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory, 1974.

Kroemer, K.H.E., "Ergonomie im Zusammenhang mit der Sicherheit am Arbeitsplatz" (Ergonomics in Relation to Work Safety), Sichere Arbeit, 27:4, 5-12, 1974.

Kroemer, K.H.E., Muscle Strength as a Criterion in Control Design for Diverse Populations, 67-89 in: Ethnic Variables in Human Factors Engineering, (Ed.: A. Chapanis), Baltimore, MD, John Hopkins University Press, 1975.

Kroemer, K.H.E., Die Messung der Muskelstaerke des Menschen (The Assessment of Human Muscle Strength), Forschungsbericht 161. Dortmund: Bundesanstalt fuer Arbeitsschutz und Unfallforschung, 1977.

Kroemer, K.H.E., The Assessment of Human Strength, 39-45 in Safety in Manual Materials Handling (Ed.: C.G. Drury). DHEW (NIOSH) Publication No. 78-185, Washington DC: U.S. Government Printing Office, 1978.

Kroemer, K.H.E., "A New Model of Muscle Strength Regulation", Proceedings, 23rd Annual Meeting of the Human Factors Society, Boston, MA, Oct. 29-Nov.1, 1979, Santa Monica, CA: Human Factors Society, 1979.

Laurig, W., Rohmert, W., and Zipp, P., "Erweiterung der Beurteilungsmethodik von Kraftmessungen bei der arbeitsmedizinischen Begutachtung" (Expansion of the Assessment Method Concerning Force Measurements for Appraisals in Occupational Medicine) Intern. Archiv Arbeitsmedizin 34, 81-95, 1975.

Marras, W.S., "Tests to Distinguish Between 'True' and 'Faked' Maximum Muscle Strength Exertions", Master's Thesis, Department of Industrial Engineering and Operations Research, Wayne State Univeristy, Detroit, MI, June 1978.

Marras, W.S. and Kroemer, K.H.E., "Evaluation of Controlled Static Muscle Exertions". Unpublished Report, 1979.

NASA, Anthropometric Source Book (3 vols.). NASA Reference Publication 1024, 1978.

Rohmert, W. und Sieber, W., "Untersuchungen ueber die Bewertung von Kraftmessungen bei der medizinischen Begutachtung" (Experiments Concerning the Evaluation of Strength Measurements for Medical Evlauations), D. Med. Sachverstaendige, 56:8, 174-177, 1960.

APPENDIX

Table A1

GENERAL INFORMATION AND INSTRUCTIONS

1. You are asked to participate in experiments designed to measure muscle strength at 100, 75, 50 and 25% of your maximal capacity.
2. The muscles efforts to be measured bring about
   - elbow flexion
   - knee flexion
   - knee extension
   - finger flexion
3. We want to perform each measurement 4 times, with rest periods in between.
4. In addition, we want to take several simple body measurements.
5. Please ask if you need further information.

Table A2

PERSONAL DATA

Sub. No: ______

Name: ______________________________ SS#: ______________

Address: ____

Phone: ________________________ Occupation: _____________

Dominant hand: Right ________ Left: _______

History of injuries or illnesses (description and date): _______

____

____

Hobbies or activities which might strengthen/weaken your arms, legs or fingers (i.e., bowling, tennis, rowing, etc.):

____

____

Table A3

SUBJECT CONSENT FORM

I, the undersigned, understand that the purpose of this study is:

a) to evaluate muscular strength,

b) to determine the test-retest variability of such strength,

c) to determine whether or not a given muscle contraction is a maximum voluntary contraction,

d) to correlate muscle strength scores with each other, and with anthropometric dimensions,

Specific tests in which I will be asked to be a subject include:

a) anthropometric measurements,

b) muscle strength measurements.

I acknowledge that I have received a complete briefing of these tests and I am satisfied that I understand what is involved.

I do not have any disorders of my cardiovascular system, or any otherdisorders or deficiencies, which make it inadvisable for me to participate as a subject in these experiments. I realize that some discomfort, fatigue and muscle strain could result from my participation, although the experimental procedures and apparatus have been designed to minimize these hazards.

I understand that my participation is strictly voluntary and that I will be allowed, at any time, to stop for rest or to discontinue my participation in this study without prejudice against me

I understand that in case of physical injury no medical treatment or compensation are offered under the research program.

Signature-Subject Date Signature-Witness Date

Table A4

ANTHROPOMETRIC MEASUREMENTS

(Garrett 1970, NASA 1978)

Stature

The vertical distance from the standing surface to the top of the head. The subject stands erect and looks straight ahead.

Buttock-Knee Length, Sitting

The horizontal distance from the most posterior aspect of the right buttock to the most anterior aspect of the right kneecap. The subject sits erect with knees and ankles at right angles.

Knee Height, Sitting

The vertical distance from the floor to the uppermost point on the right knee. The subject sits erect with knees and ankles at right angles.

Shoulder-Elbow Length

The distance from the top of the right acromion process to the bottom of the elbow. The subject sits erect with the upper arms vertical and forearms and hands extended forward horizontally.

Forearm-Hand Length

The distance from the tip of the right elbow to the tip of the longest finger. The subject sits erect with the upper arms vertical and forearms and hands extended forward horizontally.

Hand Length

The distance from the right wrist crease baseline to dactylion. The subject sits, the hand is flat on a table, palm up, with fingers together and straight.

Digit 2 Height

The perpendicular distance from the subject's right wrist crease baseline to the midpoint of the tip of digit 2. The subject sits, the hand is flat on the table, palm up, with fingers slightly separated and straight.

Crotch 2 Height

The perpendicular distance from the subject's right wrist crease baseline to the level of hand crotch 2. The subject sits, the hand is flat on a table, palm up, with fingers slightly separated and straight.

Digit 2 Length

The distance along the axis of the right digit 2 from the midpoint of the tip of digit 2 to the level of hand crotch 2. The subject sits, the hand is flat on a table, palm up, with fingers slightly separated and straight.

Hand Breadth

The breadth of the right hand between metacarpal-phalangeal joints II and V. The subject sits, the hand is flat on a table, palm down, with the fingers together and straight.

Hand Thickness

The maximum thickness of the metacarpal-phalangeal joint of digit 3 of the subject's right hand. The subject's hand is extended.

Biceps Circumference, Flexed

The maximal circumference of the right arm at the level of the biceps, with the biceps contracted. The subject stands with the elbow bent at 90 degrees and the biceps maximally flexed.

Biceps Circumference, Relaxed

The maximal circumference of the right arm at the level of the biceps, with the biceps relaxed. The subject stands with the arm slightly abducted.

Forearm Circumference, Flexed

The maximal circumference of the right forearm near the elbow. The forearm is held horizontally, elbow flexed 90 degrees and fist tightly clenched.

Forearm Circumference, Relaxed

The maximal circumference of the right forearm near the elbow. The forearm is held horizontally, elbow flexed at 90 degrees, and the forearm and finger muscles are relaxed.

Wrist Circumference

The minimum circumference of the right wrist at the level of the stylion landmark.

Lower Thigh Circumference

The horizontal circumference of the lower right thigh at the height of the musculature above the kneecap. The subject stands erect, with the weight distributed equally on both feet.

Knee Circumference, Standing

The horizontal circumference of the right knee at the level of the midpatella landmark. The subject stands erect, heels approximately 10cm apart, with the weight distributed equally on both feet.

Calf Circumference, Standing

The maximum horizontal circumference of the right calf. The subject stands erect, heels approximately 10cm apart, with the weight distributed equally on both feet.

Ankle Circumference, Standing

The horizontal circumference of the right leg measured over the medial malleolus. Subject stands erect, with the weight distributed equally on both feet.

Lever Arm

The distance between the tip of the right elbow to the distal edge of the cuff worn by the subject. The subject sits erect with the upper arms vertical and forearm and hand extended forward horizontally. The distance is reduced by 1.9cm (i.e., half the breadth of the cuff).

Lever Leg

The distance between the uppermost point on the right knee and the distal edge of the cuff worn by the subject. The subject sits erect with knees and ankles at right angles. The distance is reduced by 1.9cm (i.e., half the breadth of the cuff).

Table A5

FINAL INSTRUCTIONS - GENERAL

We are asking you to run through a series of muscle strength exercises. They include muscles of the finger, arm and leg. For each of these muscle groups we would like you to exert either 100%, 75%, 50% or 25% of your muscular capability, as specified by the experimenter.

The experimenter will tell you what muscle group and what percentage of your strength he would like you to exert in each trial. He will then give you a countdown, which goes as follows: "-2, -1, start, 1, 2, 3, 4, stop."

The period from "-2 to -1" is just a warning period so you may prepare yourself for the exertion.

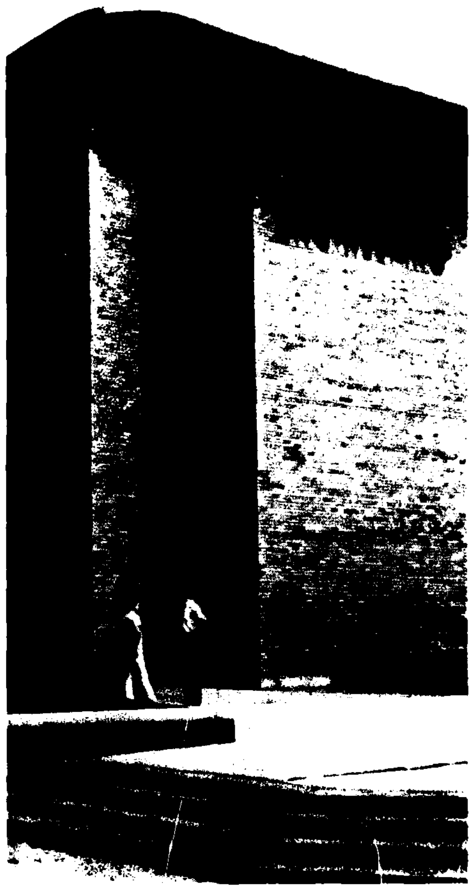
When the experimenter says "start" we would like you to build up your strength to the specified level, which would be either 100%, 75%, 50% or 25% of your strength.

About the time the experimenter says "1", you should be at that specified level. From "1" until we say "stop" we would like you to hold that level as <u>steady</u> as you possibly can.

Table A6

FINAL INSTRUCTIONS - SPECIAL INSTRUCTION TABLE

What you hear	-2 -1	Start 1	2 3 4	Stop
What you do	Get prepared. Keep muscles relaxed.	BUILD UP force to required percent level.	HOLD FORCE STEADILY at required percent level.	Relax



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